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# Development of an Android Based Performance Assessment System for Motivational Interviewing Training

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# DEVELOPMENT OF AN ANDROID BASED PERFORMANCE ASSESSMENT SYSTEM FOR MOTIVATIONAL INTERVIEWING TRAINING

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By

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Sowmya Pappu ENTITLED Development Of An Android Based Performance Assessment System For Motivational Interviewing Training BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science.

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ABSTRACT

Pappu, Sowmya. M.S. Department of Computer Science, Wright State University, 2017. Development of an Android Based Performance Assessment System for Motivational Interviewing Training

Motivational Interviewing (MI) has been proved to be an effective Screening, Brief Intervention, and Referral to Treatment (SBIRT) technique. It is an evidence-based practice used to identify, reduce, and prevent problematic use, abuse, and dependence on alcohol and illicit drugs. It emphasizes on patient-centered counseling approach that can help resolve their ambivalence through a non-confrontational, goal-oriented style for eliciting behavior change from the patient, almost like patients talk themselves into change. This approach provokes less resistance and stimulates the progress of patients at their own pace towards deciding about planning, making and sustaining positive behavioral change.

Thus, training medical professionals to provide supportive care and adapt MI techniques plays a major role in not only improving their skills but also has follow-on impacts for patients to a large extent. The training, such as workshops (Role-plays and videos), help professionals learn about MI to improve the quality and effectiveness of counseling and consultations with patients.

In this thesis research, we have developed an android based performance assessment system to assist the MI training by providing objective assessment and instantaneous feedback to the trainee about his or her performance and progress through

the training sessions. It also provides the trainers with evidence to develop individually customized training sessions to address the specific needs of each trainee in order to achieve improved outcome from the training. In our prototype design, we have explored the use of automatic speech recognition, grammar-based MI analysis in a mobile/cloud hybrid solution. Particularly, we have extended the Android's voice command interface to support the automatic scripting of a long-time conversation. Furthermore, we have assembled a user-friendly system which only uses smartphone/tablet and can be easily used by professionals without hassle. Through our experimental studies, our system has demonstrated sufficient accuracy and robustness to distinct between a good and bad interview, and has potential to grow into an effective assessment tool for MI training and practice.

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# CHAPTER 1

## 1.1 Introduction

What is Motivation? Why is it important in the context of patients in a health crisis?

Motivation is the willingness of someone to accomplish goals. Particularly, in the treatment of patients with an addiction, motivation is essential for progression. An estimated 50% of mortality from the 10 leading causes of death is due to individual health related behavior, which suggests that the patient's empowerment and involvement in taking care of their own health by adopting behavioral modification strategies would have important significance [1, 2]. Over the past 15 years' considerable research and clinical attention have focused on ways to move an individual away from a state of indecision and uncertainty and towards the change of recovery.

Motivational Interviewing (MI) is a technique to assist a patient in the process of making positive behavioral changes for better health. It emphasizes on patient-centered counseling approach that can help resolve their ambivalence. MI is a non-confrontational, goal-oriented style for eliciting behavior change from the patient, almost like patients talk themselves into change. This approach provokes less resistance and stimulates the progress of patients at their own pace towards deciding about planning, making and sustaining positive behavioral change. The main goals of MI are to engage patients, elicit change talk

in such a way that the patients move from not even considering changing their behavior to being ready, willing, and able to do so.

The benefits of employing motivational enhancement techniques include [3]:

- To get motivated in a healthy way towards change.
- Preparing patients to reduce ambivalence toward therapy
- Patient retention is a good measure for checking how well the services are engaging the patients.
- Increasing participation and involvement such that the patient, rather than the counselor, voice the arguments for change.
- Improving treatment outcomes. Research evidence have shown that all the motivational enhancement techniques have significantly better outcomes.
- Encouraging a rapid return to treatment without any hesitation if symptoms recur which helps building their consistency.

Figure 1: General Scenario at an interview

### 1.2 History of motivational interviewing

The concept of MI was introduced by David Miller and Rollnick in 1980s when treating people with alcohol abuse which was in contrast with the confrontational counseling

approaches that were followed during that time [4]. Therapeutic confrontation has been defined as an open, honest and a reality-oriented feedback of a person's self-defeating behavior, attitude and beliefs provided by the therapist. This approach pressurizes the patient to change which can cause them to feel defensive and could lead to a higher level of patient resistance. This would essentially harm the quality of treatment.

Table 1: Comparison of Confrontational and Miller approach

| **Confrontational Approach** | **Millers Approach** |
|---|---|
| ▪ Patient is forced to change<br>▪ Therapist functions as a unidirectional information delivery system<br>Example: I know what you need | ▪ Patient wants to change<br>▪ Therapist understands the person's frame of reference and encourages his/her motivation for change<br>Example: You have what you need |

Miller described MI as a pragmatic patient-centered counseling approach which would enhance intrinsic motivation for change. Miller published an article in 1983 describing a way of talking with people to evoke and strengthen their personal motivation for change by exploring and resolving ambivalence. This article was focused on using this approach for people with alcohol problems.

Later, Miller and Rollnick collaborated on the first book on MI which was published in 1991. The authors described first principles of MI and use of specific communication skills and strategies. This generated a great deal of interest from the research world during the 1990s. A second and third edition of the book were published in 2002 and 2012 respectively, refining the MI approach [5]. Thus, MI was increasingly used

in various health care settings other than those dedicated to addictions and shows no signs of slowing down.

Figure 2: William Richard Miller and Stephen Rollnick (Co-founders of MI)

### 1.3 When is motivational interviewing used?

MI was created with addiction in mind but now it is being applied to various fields that include [6]:

- Depression
- Anxiety
- Substance dependence
- Gambling problems
- Parenting
- Helping patients change behavior
- Treatment of psychological problems

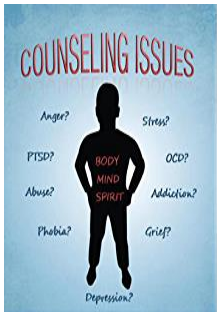


Figure 3: Different types of counselling issues

### 1.4 Principles of motivational interviewing

MI consists of 4 principles that are practiced and followed by therapists throughout treatment. They are [4]:

1. **Express empathy through reflective listening**: The expression of empathy is crucial in providing the basis for patients to be heard and understood. By doing this, the patient becomes more open and free to share their experiences in depth. Due to the lack of criticism and judgement, the patient feels personally accepted and valued which is one of the core values of MI.
2. **Development of discrepancy**: It involves exploring the pros and cons of what patients are doing and how their present behavior conflicts with their significant personal goals. When an individual begins to understand that his/her current situation might lead them away from, rather than toward their important goals, only then change is more likely to occur.
3. **Roll with resistance by avoiding argument and direct confrontation**: The therapist tries to understand the patient's perspective and then reframes the statements such that they de-escalate and avoid a negative interaction by providing alternative ways of thinking for the patient to consider. The MI value which is not to force or manipulate the patient into acceptance, leaves a little for the patient to resist.
4. **Support optimism and patient self-efficacy**: To succeed in changing, patients must believe that they have the resources and capabilities to reach their goals. Therapists focus on previous successes of patients and support optimism by showing other patients as role models. It is important to encourage them to embark

on achievable small steps that they believe are feasible in the process of recovery. Providing affirmation for the small steps taken to overcome barriers is very critical to keep the patient motivated towards the change.

### 1.5 Stages of change

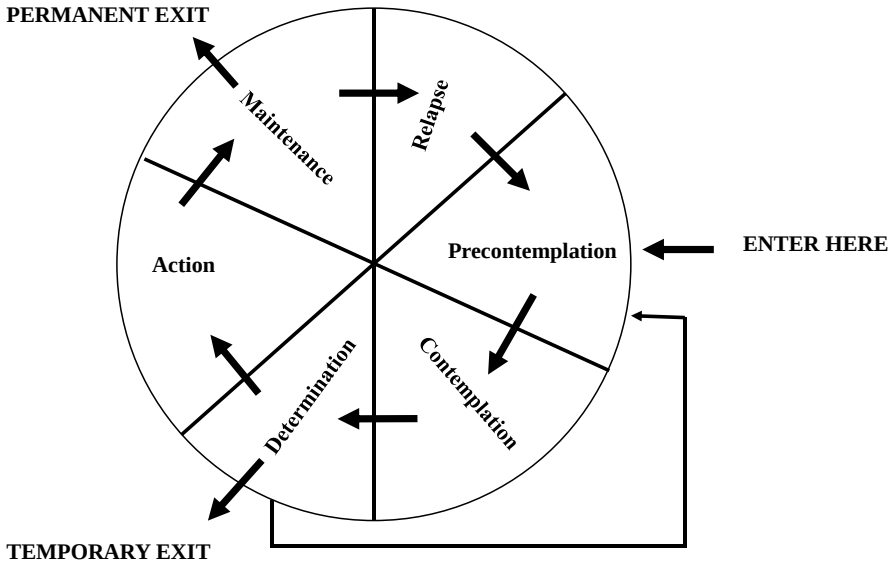


Figure 4: Different stages of change

Table 2: Summary of characteristics and counselor's goal in various stages

| STAGES | CHARACTERISTIC | COUNSELOR GOAL |
|---|---|---|
| Pre-contemplation | Unwilling/Having no intentions to change. A patient in this stage is unaware of the consequences of their problem behaviors. | ▪ Raise Awareness.<br>▪ To get patient to consider they have a problem and then encouraging them to think about it. |
| Contemplation | Aware of the problem and intends to change, but are ambivalent. | ▪ Resolving ambivalence.<br>▪ To guide the patient in making decision to act. |

| | | |
|---|---|---|
| Determination | Accepts responsibility and is committed to change but are still considering which actions to take. | ▪ To help the patient in developing a realistic plan for change.<br>▪ To explore the patient's options for treatment. |
| Action | Actively takes action to change but have not yet stabilized in the process. | ▪ To help the patient by guidance and support in addressing barriers to change.<br>▪ To engage the patient in treatment by preventing relapses. |
| Maintenance | Has achieved initial goals and is working to focus on relapse prevention and consolidate gains. | ▪ Reinforce motivation and acknowledge positive changes.<br>▪ Developing new skills to support continued change. |

**1.6 What is the difference between a good and a bad interview?**

A ***good interview*** is the one in which the basic approach of MI is used. **OARS** is a brief way to remember it where **O** stands for open-ended questions, **A** stands for Affirmations, **R** stands for Reflections and **S** stands for Summaries [5,7].

- ✓ **O**pen-ended questions encourage people to talk and express their feelings in their own words without leading them in a specific direction which helps the therapist to establish rapport with the patient and increase understanding. These questions require more thought and cannot be answered with a single phrase or word, for example, YES or NO. Open-ended questions give the patient, control

of the session and keeps the communication moving forward. Thus, this helps the patient to explore the reasons for possibility of change.

Example: How is smoking interfering with your life at this point?

- ✓ The use of **A**ffirmations helps in building confidence in one's ability to change even when their previous efforts have been unsuccessful. Affirmations are statements and gestures that recognize patient strengths. More broadly, your affirmation acknowledges behaviors that lead in the direction of positive change.

  Example: You have tried very hard to quit.

- ✓ **R**eflective listening is a challenging skill supporting the goal-oriented aspect of MI. This serves as roadblocks to effective listening as it demonstrates that you have accurately heard and understood the issues from the patient's perspective by restating its meaning. It helps to reduce ambivalence and reinforces motivation.

  *"Reflective listening is a way of checking rather than assuming that you know what is meant"* (Miller and Rollnick, 1991, p. 75).

  Example: And you wonder if that might be because…

- ✓ **S**ummaries are a special application of reflections where the therapists periodically summarize all or a part of a counseling session(s). They can provide a stepping-stone towards change by exposing the discrepancies of the patient. It is a good way to ensure that there is clear communication between the therapist and the patient. Also, provides a natural bridge during the patient's transition between stages of change.

Example: Let me see if I understand so far…

### 1.6.1 An example of a good interview [8]

Figure 5: Example of a good interview

**Doctor:** I wrote a prescription for antibiotics for Eden. I just want to talk to you though. I am a little bit concerned looking through his chart that how many ear infections he has had recently and I noticed that you had checked the box that someone smoking in the home so I was wondering if you can tell me a little more about that.

**Patient:** Well, it's just me and him and I do smoke. I try really hard not to smoke around him but I have been smoking for 10 years except when I was pregnant with him but everything is so stressful being a single mom and having a full-time job and so it is just that is why I started smoking again.

**Doctor:** You have a lot of things going on and smoking kind of a way to relax and destress.

**Patient:** Yes. Some people have a glass of wine, I have a cigarette.

**Doctor:** Sure, and it sounds like you are trying not to smoke around him. Why did you make that decision?

**Patient:** I know that it's not good for him. I mean I have read those things about ear infections and asthma and stuff. But other kids have ear infections and their parents don't smoke.

**Doctor:** So, on one hand you are worried about how your smoking might be affecting him and on the other hand you are not so sure if it's really the smoking that is causing these problems.

**Patient:** Right. Yeah. I mean he doesn't have asthma. I don't. He hasn't had a lot of other problems that his other friends have. And I have thought about quitting before in the past but I just don't see how it is possible right now.

**Doctor:** What made you decide to quit smoking when you were pregnant?

**Patient:** Well, he was inside me and we were sharing everything and I knew that he would get some of that and I didn't think I could live with myself if something happened to him.

**Doctor:** Right now, it feels almost too difficult to even manage or even to try.

**Patient:** Yeah exactly.

**Doctor:** How are you successful when you quit before?

**Patient:** I don't know. I think about it now, I don't even know how I did it. I just did it. I just couldn't imagine like him not being born or going into labor early and him having problems and stuff like that. All the stuff that they talk about women who smoke and so that was just enough to say OKAY! You know what I am not going to risk that.

**Doctor:** Risks were so scary then that you were able to stop but they don't feel as scary to you now.

**Patient:** No. I mean we are 2 separate people and like I said I try really hard not to smoke around him. I am good about that. I don't let other people smoke around him.

**Doctor:** You are doing the best you can do.

**Patient:** Yes

**Doctor:** Okay. But it sounds to me to like part of you really does want to quit.

**Patient:** Yeah, I know that I need to and you know every new year I say okay this year I am going to quit smoking but then something happens and it just doesn't.

**Doctor:** It's on your to do list but it's just not making it to the top.

**Patient:** Yeah.

**Doctor:** If you did decide to quit on a scale of 1 to 10 where one is not at all confident, you don't think you could do it and 10 is you feel pretty certain that you could. Where do you think you fall right now?

**Patient:** Probably, like a five. Kind of an unsure area, like I know I have done it before so I know I can do it but at the same time it just seems really hard and it's not the same situation.

**Doctor:** What made you say five rather than two or three?

**Patient:** I know all the ways its bad for me and I don't want him to grow up thinking that it's okay to smoke. I don't want him to chew or anything like that. So, I know I need to especially before he gets old enough to understand what mommy is doing but I just don't know if I can do it.

**Doctor:** Okay so it sounds like you have a lot of reasons why you would like to quit. You have been successful quitting in the past and right now you are just feeling a little bit hesitant about your ability to do it.

**Patient:** Yeah.

**Doctor:** Where do you think we should go from here?

**Patient:** I don't know. I would like some help. I just don't know what kind of help I need.

**Doctor:** Sure. Well, if you would be interested that is something I can definitely talk to about. There are a lot of new options that can actually help people be way more successful in their attempted quitting. There is different medications you can try.

**Patient:** I don't like medicine.

**Doctor:** Okay. There is also a lot of support groups and classes that you can take where you have other people to go through it with you and sometimes just having that support can be a big part of it especially for people like you where smoking is such a stress-reliever.

**Patient:** That sounds nice but I am not sure if I have the time for all that.

**Doctor:** Sure. It feels like something that would take up a lot of time and may be not fit into your life. I wonder if we could talk about some options that might fit into your life.

**Patient:** That would be really nice.

**Doctor:** Okay. Well, if you are willing then we could set up another appointment where you could come in and we could talk more about that.

**Patient:** I would like that. That would be great.

**Doctor:** Great.

**Patient:** Thank you.

**Doctor:** Sure.

A ***bad interview*** is the one which is in complete contrast with the above-mentioned approach. Such interview includes many closed questions that elicit a limited response. Closed questions do not facilitate dialog and thus the therapist ends up talking for most of the time in the interview.

Example: Are you feeling better today?

### 1.6.2 An example of a bad interview [9]

Figure 6: Example of a bad interview

**Doctor:** Okay, so I wrote a prescription for antibiotic for Eden that should help with the ear infection but in looking through the chart I mean it seems like he has had 6 or 7 of these just in the past year or so. That is really a big problem.

**Patient:** Yeah! It's stressful for both of us. I think it's really upset.

**Doctor:** Well, one of the primary risk factors for multiple ear infections in kids is actually smoke exposure. Are you smoking?

**Patient:** Yeah, I do smoke but I don't smoke around him. I try really hard not to smoke around him.

**Doctor:** Well, the fact that he is having these ear infections is indicating to me that he is being exposed to smoke and so what can you tell me about that?

**Patient:** I don't know. I mean I try really hard not to smoke around him. I don't smoke in the car, when he is home I go outside to smoke. I know it's bad and I know it's bad for him so I don't want him to be around it so I try really hard.

**Doctor:** I really need you to quit smoking both for your health and for Eden. Did you know smoking around your child is associated not only with ear infections it could get to the point where you have to put tubes in his ears pretty shortly here. Also, things like vitamin C deficiency, cavities like dental cavities, behavior problems, asthma, other upper respiratory infections. It's really putting him at a lot of risk. In addition to that, kids of smokers end up smoking themselves. Do you want him to grow up to be a smoker?

**Patient:** No, but I don't smoke. I have thought about quitting but it's just really hard so I just don't know how to do it.

**Doctor:** Well, now is the time to quit. It's really gotten to the point where you can't keep smoking not only for him like I said but also for you. You are putting yourself at risk for lung cancer, for emphysema, for oral cancers, for heart disease, for all kinds of these.

**Patient:** I know. I have heard people told me before. I have heard all that. I just don't know how to do it. How am I supposed to quit? It's so hard.

**Doctor:** Well, there is all kinds of things you can use now. It is not as hard as it used to be. You can use nicotine replacement, there's patches, there's lozenges, there's gum, there's inhaler, there's nasal spray. We can talk about medications you can try Chantix, you can try zyban. There is quit smoking groups you can go to, there is hotlines you can call and talk.

**Patient:** I just don't have time for any of that.

**Doctor:** There is no reason why you shouldn't be able to quit. This is really important.

**Patient:** I understand that. I know it is. I mean everybody has problems right. It is really hard.

**Doctor:** Well, what can be more important to you than the health of your child.

**Patient:** I don't know.

**Doctor:** I really need you to tell me that you are going to quit smoking, this is really important.

**Patient:** I will go look at all those things and I will try to find something and I will talk to my doctor about it.

**Doctor:** Okay. Well, I think you really need to think about this seriously. Like I said it's really putting yourself and your child in danger.

**Patient:** Okay. Whatever. Okay

**Doctor:** Okay.

### 1.7 Why do we need to train doctors for motivational interviewing?

MI has been used in many behavioral health care problems for years now. The scores of research studies demonstrate that MI has major impact on health-related behavior change and the success of this is influenced by the skills and characteristics of the therapists offering MI. The most important skills that these therapists should possess include empathy, reflective listening, communication skills and not being too judgmental.

Application of MI to everyday patient interactions has the potential to help patients retain control and play an active role in their own healthcare. Also, the techniques have been evaluated in randomized clinical trials and found to be effective in contributing to positive health outcomes and improved patient-physician communication. Thus, training professionals to provide supportive care and adapt MI techniques plays a major role in not only improving their skills but also has follow-on impacts for patients to a large extent. Therefore, these principles should be incorporated into physician and medical-student training [10].

The training techniques that help professionals learn about MI to improve the quality and effectiveness of counseling and consultations with patients include [10]:

- Workshops (Role-plays and videos) rather than Self-study (Training materials)
- Applying techniques to own behavior
- Supervision: Face-to-face or Telephone
- Distance learning: Videos, Online courses and toolkits.
- Practicing with other trainees/simulated patients.

**MINT** (The **M**otivational **I**nterviewing **N**etwork of **T**rainers) is an international organization of trainers started in 1997 by a small group of trainers trained by William R. Miller and Stephen Rollnick. It promotes research and training of MI [11].

Figure 7: Scenario at workshops for training doctors for MI

## 1.8 What is the need of developing an android application?

Smartphones are everywhere. In today's tech-savvy world, smartphones and tablets are one of the most popular forms of communication. They are more like personal computers providing information at our finger tips. They have a wide variety of uses that can save us time and make us more efficient and productive.

In recent times, global mobile space is becoming increasingly crowded with a variety of smart apps that come in handy for various functionalities. It is also so much easier to access a mobile app than a mobile website. The app once downloaded, stays on the device and can be opened with just a tap while the website must be opened using a web browser and then typing in a URL. A well-designed app can be the most significant tool a person can take advantage of.

Now comes the question **WHY ANDROID?**

Freedom and Innovation is the key to android app development. Android is free and an open source platform. It allows the developers to create amazing applications that are scripted in Java language with the help of a rich set of libraries and at the same time the native android apps can be easily ported to other mobile operating systems. One of the major benefits of Android App Development is that it is easy to build as it allows the developers some smart features attached to it, also easy to test and evaluate.

Training is one such field where apps can play a major role. The main aim of this research is to develop an android app for training purposes in the field of MI. The prototype that we have developed helps the trainers in assessing the progress of the trainees. It evaluates and summarizes the performance of the trainees after every workshop session. To be precise, this app helps the trainers by saving time from the evaluation.

Figure 8: Feasibility in using mobile applications

## CHAPTER 2

## Speech Recognition (Speech to Text)

Figure 9: Speech to text conversion

### 2.1 What is Speech Recognition?

Speech Recognition is the ability of a machine to allow spoken input and convert it into readable text in real-time.

Our mobile devices have improved so much at understanding us. Now-a-days, you can talk to your computer or phone and your speech acts like a trigger for performing some action. For example, you can place a call to a contact by just saying “Call Home” or you can perform an action like “Switch on Bluetooth” or you can type with your speech by dictating it to your phone. This technology is being widely used to make devices more user-friendly by replacing other input methods like typing or clicking.

### 2.2 How it works?

The device identifies and understands spoken words by converting the analog sound waves to digital audio and then by matching its pattern against the stored patterns.

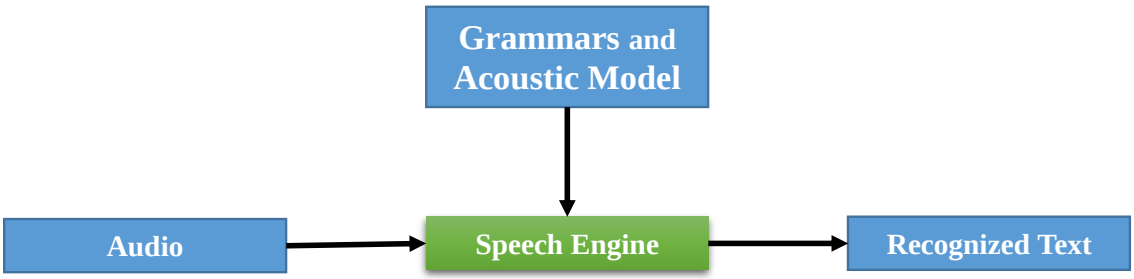


Figure 10: Speech to text conversion process

The process of this speech to text conversion is stated below [12]:

- The audio stream is processed by isolating segments of sounds and converting them into series of numeric values (i.e., digital format).
- The speech engine takes the digital format produced in the above step and searches across 2 databases:
  - The Acoustic model: It breaks the word into phonemes (Phonemes are smallest unit of sound in speech).
  - The Language model: It compares the phonemes to words in its dictionary. Using grammars can increase the accuracy of recognition by constraining the recognizer to listen only for speech that is meaningful to the application.
- Then converts the phonemes into words, thus, determining what the user was probably saying.

These models can be specialized for a given language, application domain etc., to best transcribe the speech. The overall goal is to accurately and efficiently convert speech to text independent of the environment or the device used for recording the speech (i.e., the microphone).

## 2.3 Applications of Speech Recognition

As the technology improves it is being implemented in several other areas other than the major applications listed below [13]:

- Telecommunications
- Personal Assistant
- Car Bluetooth
- People with Disabilities
- Military
- Health Care
- Home Automation

## 2.4 Difference between Speech Recognition and Voice Recognition

Table 3: Difference between the terms speech recognition and voice recognition

| SPEECH RECOGNITION | VOICE RECOGNITION |
|---|---|
| Understanding the words being spoken | Identification of the person speaking |
| Language dependent | Language independent |
| It is used to detect the words and their meaning but has nothing to do with the biometrics of a person's voice.  | Biometrics of a person's voice is analyzed to detect the speaker. Everyone has a unique voice pitch, accent, speaking style etc. It is used more like a fingerprint. Security is the major field where this is applied. For example, solving crimes, a |

| | |
|---|---|
| | hands-free AI assistant that knows who you are etc.<br>  |

### 2.5 Overview about the different Speech Recognition Systems

Here are some of the best Speech Recognition Systems in order of accuracy [14]:

1. **Baidu:** It is described as "the Google of China" and is the country's biggest search engine. The software it uses, Deep Speech 2, takes advantage of the power of cloud computing and machine learning to create a neural network (i.e., the machines that learn). It was developed by listening to thousands of user-submitted voice data while simultaneously reading their transcriptions. Typing in mandarin is not as easy as it is in English due to the massive mandarin alphabet. Hence, it is more popular in China.


Figure 11: Baidu Speech Recognition System

2. **Hound:** The Hound app, is a digital assistant that hopes to make human-device interaction as natural as possible which means we don't have to modify our speech for the software to understand. Its speed and accuracy is due to the combination of speech recognition and language understanding which is known as its Speech-to-Meaning capability. It understands both context and details.

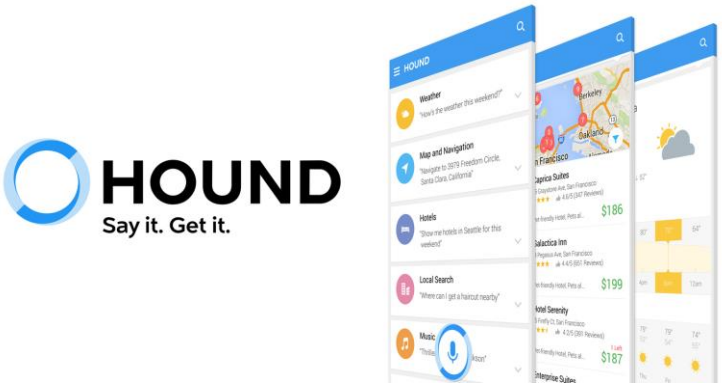


Figure 12: Hound Speech Recognition System

3. **Siri:** Apple's Siri is the most-used personal assistant in America. It adapts to the user's individual language usage and individual searches with continuous use. Siri is programmed to respond to casual speech.

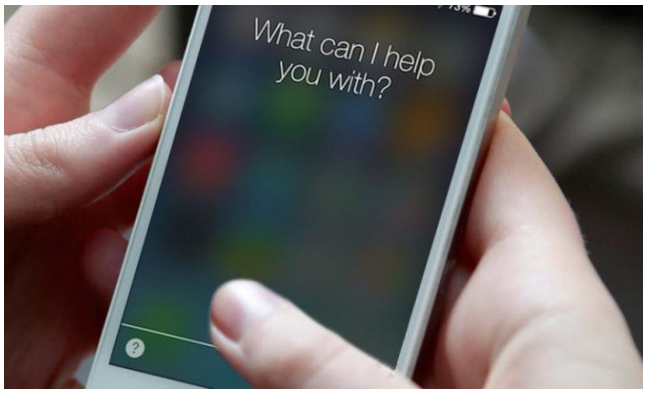


Figure 13: Siri Speech Recognition System

4. **Google Now:** Google Now cards are a major advantage when it comes to recognizing repeated actions that a user performs on the device and to display more relevant information like common locations, search queries etc. Its predictive power, ability to remind users of events based on history of locations or check-ins and improvement in accuracy in loud places are some features that can help it outperform Siri and Cortana.

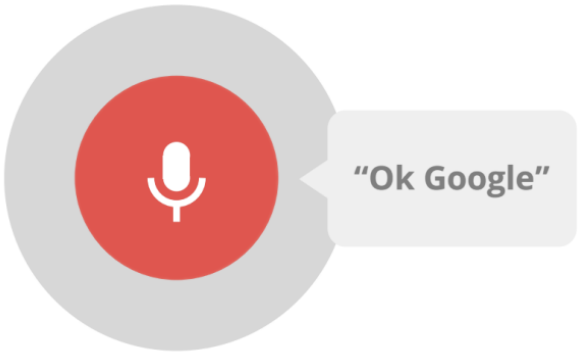


Figure 14: Google Now Speech Recognition System

5. **Wit.ai:** It is used by the developers to easily build a voice interface for their application which would help in providing a hands-free experience while driving, cooking etc. For turning speech into actionable data, Wit combines various advanced natural language processing techniques and several speech recognition engines for bot makers.


Figure 15: wit.ai Speech Recognition System

6. **Microsoft Cortana:** Cortana is a personal digital assistant created by Microsoft and now built into Windows 10. It helps organize day-to-day activities along with regular web searches (i.e., Bing search engine) for information. It recognizes natural voice without requiring keyboard input and learns over time to become useful every day.

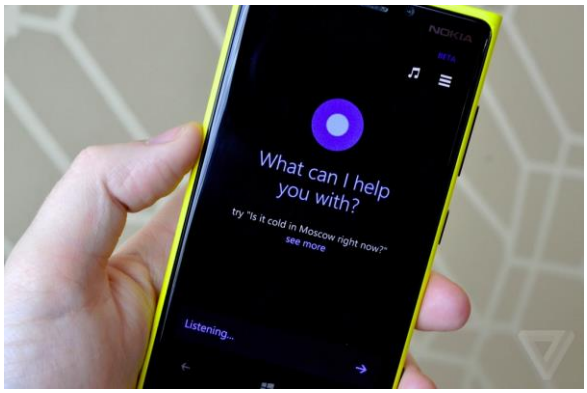


Figure 16: Cortana Speech Recognition System

7. **Amazon Alexa:** Alexa Voice Service (AVS) adds intelligent voice control to any connected product that has a microphone and a speaker. It is used for music-playback, making to-do lists, controlling other smart home products, providing weather and other real-time information. The main features of Alexa include Voice-ID and its ability to operate from next room while others require the speaker to be within a few feet of its microphones.


Figure 17: Alexa Speech Recognition System

## 2.6 Limitations of Speech Recognition

- Quality of input: The quality of input depends on the microphone's quality being used. A speech recognition engine performs better when listening to speech over higher quality and higher bandwidth mediums. Thus, the microphone's poor quality would affect recognition of speech which would lead to errors while transcribing it.
- Potential for misrecognition: Speech recognition engines do not understand the context of the speech, the way humans can, leading to errors due to misinterpretation. Errors can also arise due to several other problems like slang, speaking too fast, usage of technical words and acronyms.
- Noisy environment: Systems don't work efficiently if there is a lot of background noise because they may not be able to differentiate between the user's speech and other voices leading to transcription errors.
- Accents and Speech Recognition: Individuals have their own speaking styles depending on many factors like accents, dialect etc. These individual differences introduce a challenge for current speech recognition technologies.

## 2.7 What is an Application Programming Interface (API)?

APIs are sets of routines, protocols that govern the communication between various applications without any user knowledge. In other words, they are software-to–software interfaces. Popular API examples include Google maps API, YouTube API etc. A good API provides all the building blocks for the programmer to develop a program. It also serves as a layer of security such that it limits program access to a specific set of features-what functionality is available, how it must be used, input and output formats etc.

The disadvantage of using APIs is that it may not be always available for use which would affect the applications that depend on those APIs.

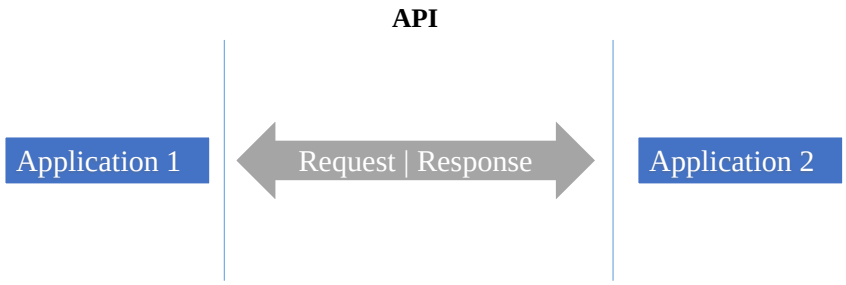


Figure 18: Application Programming Interface (API)

### 2.7.1 Android Speech Recognition API

Android Speech Recognition API is open to everybody, and thus, allows the developers to perform both online and offline speech recognition in order to convert speech input to text. Online speech recognition is carried out with the help of a server in the background since the device is connected to the network while the offline speech recognition is carried out by downloading language packages to the device.

The main advantage of this API is that it can work efficiently even without internet connection whereas the other APIs such as google cloud speech API and IBM Watson speech recognition API will not be able to stream results in the absence of network.

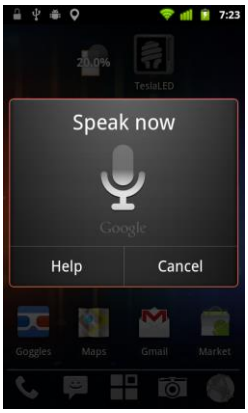


Figure 19: Android Speech Recognition API

### 2.7.2 Google Cloud Speech API

Google cloud speech API assists the developers to convert an audio into a text using powerful neural network models. It has the ability to recognize over 80 languages and variants so that people all around the globe can use it. While the user is speaking, it can stream text results in real time and the interim results are returned to the user as and when they become available.

The other features of this API include: providing accurate results in noisy environments and availability of context-aware recognition which are two of the limitations of speech recognition stated above. Thus, showing that google cloud speech API is much more efficient than the android speech recognition API. The limitations of using this API would be security of the data and the cost associated for using this API in our applications [16].


Figure 20: Google Cloud Speech Recognition API

### 2.7.3 IBM Watson Speech Recognition API

IBM Watson speech recognition API has the capability to provide transcription using machine intelligence which is a combination of information about language structure and grammar.

In contrast to google speech API, it only supports few languages such as Brazilian Portuguese, French, Japanese, Mandarin Chinese, Modern standard Arabic, Spanish, UK

English and US English. The advantage of this API is its ability to distinguish speakers in a conversation. The other features of this API are: It can return alternative and interim transcription results and can format dates, times, numbers into a user-friendly form [17].

Figure 21: IBM Watson Speech Recognition API

# CHAPTER 3

## System Design and Development

A major effort and contribution of this research is to successfully design and develop a prototype system that can be easily used by the health care professionals to train doctors in Motivational Interviewing. This chapter provides details about the system design workflow.

### 3.1 About Android Lifecycle Methods

Android is a powerful mobile operating system which supports a large number of applications ("apps") in smartphones. Android began its life as Android Inc. which was a Palo Alto-based startup company founded in 2003 by Andy Rubin, Rich Miner, Nick Sears and Chris White. Later in 2005, Google acquired this company.

An activity is the representation of a single screen with user interface, and forms a fundamental building block of applications on the android platform. The activity instance can exist in number of different states in their lifecycle. The appropriate lifecycle method is called whenever there is a change in state, allowing it to adapt to that change by executing the code under that method. This activity lifecycle is important in order to be a part of a reliable application. The 7 lifecycle methods are described below:

Table 4: Summary of Android Lifecycle methods

| Method | Description |
|---|---|
| onCreate() | This is the first callback. It is called when the activity is first created. |
| onStart() | Called when the activity becomes visible to the user. |
| onResume() | Called when the user starts interacting with the application. |
| onPause() | Called when activity is not visible to the user. It is called when the previous activity is being resumed. |
| onStop() | Called when activity is no longer visible to the user. |
| onRestart() | Called after your activity is stopped, prior to it being started again. |
| onDestroy() | This is the final callback. It is called before the activity is destroyed by the system. |

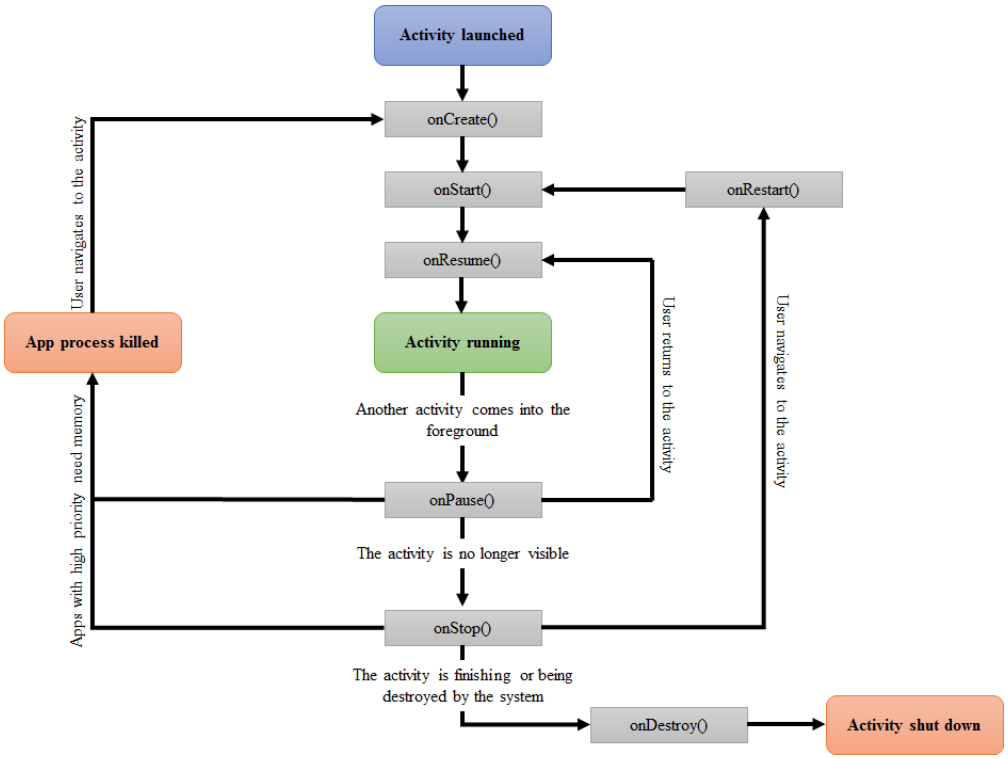


Figure 22: Android Lifecycle

### 3.2 About Android Studio

Due to the open nature of Android, it gives a great platform for developers in building powerful apps that take the advantage of latest hardware capabilities available on each device. These apps are written using the Android software development kit (SDK) and often the Java programming language.

I have used Android Studio which is the official integrated development environment (IDE) for the android application development. The advantage of using this IDE is that it accelerates development by providing fastest tools like code editing, debugging, a flexible build system and an instant build/deploy system for building highest-quality apps. The apps could easily be tested on android emulators that simulate a device and display it on our computer without having to use a hardware device. These emulators support phone, tablet, Android Wear and Android TV. Other features also include: instant runs that can be performed to push changes made to the app without building a new APK (i.e., Android Package Kit is a package file format used for installing the apps and middleware on mobile operating systems) and provision of a unified environment to develop apps for all android devices.

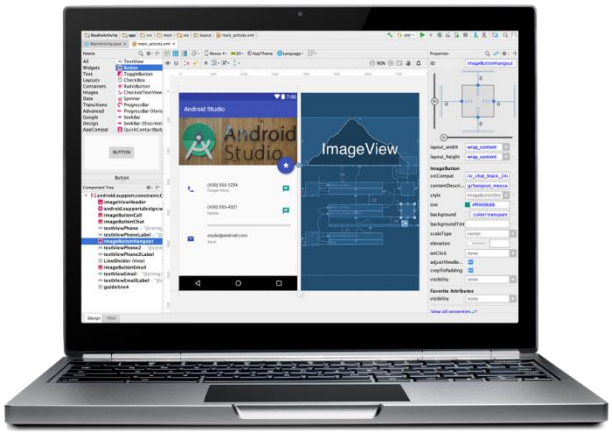


Figure 23: Android Studio

### 3.3 Android Speech Recognition API in detail

Android uses “android.speech” package to convert speech input to text.

This “android.speech” package supports [15]:

- Interfaces: RecognitionListener
- Classes: RecognitionService, RecognitionService.Callback, RecognizerIntent, RecognizerResultsIntent, SpeechRecognizer.

I have used the functionalities of SpeechRecognizer class for developing my application. This class provides the means to start, stop and monitor speech recognition service in an application. Speech recognition is done with the help of a server in the background. RECORD_AUDIO permission of the application is necessary to use this class.

Table 5: Constants involved in Android SpeechRecognizer class [15]

| | |
|---|---|
| String | CONFIDENCE_SCORES<br>Key used to retrieve a float array from the Bundle passed to the onResults (Bundle) and onPartialResults (Bundle) methods.<br>Confidence values close to 1.0 indicates high confidence which implies speech recognizer is confident that the recognition result is correct. And the values close to 0.0 indicate low confidence. |
| Int | ERROR_AUDIO<br>Audio recording error. |
| Int | ERROR_INSUFFICIENT_PERMISSIONS<br>Insufficient permissions |

| | |
|---|---|
| Int | ERROR_NETWORK<br>Other network related errors. |
| Int | ERROR_NETWORK_TIMEOUT<br>Network operation timed out. |
| int | ERROR_NO_MATCH<br>No recognition result matched. |
| int | ERROR_RECOGNIZER_BUSY<br>RecognitionService busy. |
| Int | ERROR_SERVER<br>Server sends error status. |
| Int | ERROR_SPEECH_TIMEOUT<br>No speech input. |
| String | RESULTS_RECOGNITION<br>Key used to retrieve an ArrayList<String> from the Bundle passed to the onResults (Bundle) and onPartialResults (Bundle) methods. |

Table 6: Public methods involved in SpeechRecognizer class [15]

| | |
|---|---|
| Void | cancel()<br>Cancels the speech recognition. |
| static<br>SpeechRecognizer | createSpeechRecognizer(Context context)<br>Factory method to create a new SpeechRecognizer. |
| static<br>SpeechRecognizer | createSpeechRecognizer(Context context, ComponentName serviceComponent) |

| | |
|---|---|
| | Factory method to create a new SpeechRecognizer. |
| Void | destroy()<br>Destroys the SpeechRecognizer object. |
| static boolean | isRecognitionAvailable (Context context)<br>Checks whether a speech recognition service is available on the system. |
| void | setRecognitionListener(RecognitionListener listener)<br>Sets the listener that will receive all the callbacks. |
| Void | startListening(Intent recognizerIntent)<br>Starts listening for speech. |
| Void | stopListening()<br>Stops listening for speech. |

Before dispatching any command to the created SpeechRecognizer we need to set the listener to receive all the callbacks. The listener class implements the RecognitionListener interface. This interface has methods that are used for receiving notifications from the SpeechRecognizer when the recognition related events occur. The following table gives the summary of all the methods declared in the interface.

Table 7: Public methods involved in RecognitionListener interface [21]

| | |
|---|---|
| abstract void | onBeginningOfSpeech()<br><br>The user has started to speak. |
| abstract void | onBufferReceived(byte[] buffer)<br><br>More sound has been received. |
| abstract void | onEndOfSpeech()<br><br>Called after the user stops speaking. |
| abstract void | onError(int error)<br><br>A network or recognition error occurred. |
| abstract void | onEvent(int eventType, Bundle params)<br><br>Reserved for adding future events. |
| abstract void | onPartialResults(Bundle partialResults)<br><br>Called when partial recognition results are available. |
| abstract void | onReadyForSpeech(Bundle params)<br><br>Called when the endpointer is ready for the user to start speaking.<br><br>params: Parameters set by the recognition service. |
| abstract void | onResults(Bundle results)<br><br>Called when recognition results are ready |
| abstract void | onRmsChanged(float rmsdB)<br><br>The sound level in the audio stream has changed. |

Our system design uses both the online and offline speech recognition of android speech API. The online speech recognition is carried out when the devices are connected to the network, while the offline speech recognition is carried out when the devices do not have access to internet connection. For offline recognition, the language packages should be downloaded to the device.


Figure 24: Online Speech Recognition

As seen from the flowchart, the user's speech is sent to the server (i.e., cloud) and the recognition engine on the server then converts the speech to text and sends it back. The android device is used as a medium to take the speech input and to display the text output, that is received from the server, on the device's screen while the android speech API is responsible for controlling the flow of the input and output to and from the server respectively. Since, this involves a lot of communication with the cloud, we need to have access to the internet to make use of the speech recognition service.


Figure 25: Offline Speech Recognition

The offline speech recognition is carried out locally on the user's device by making use of the downloaded language packages. Here, the user's speech is converted to text locally and is displayed to the user on his/her screen.

### 3.4 Improving the system design from a question to a lengthy conversation

By default, the android speech recognition can support a speech input that is continuous which means there are no pauses in the spoken input. For example, if the user starts the speech recognizer and asks, "How are you? *pause*", the listener stops and displays recognition results i.e., the text. This happens because the listener assumes the user has stopped speaking as there was a pause. This design is valid in case of google now because we use it for single questions/sentences most of the time. For example, we use google now for asking questions like "How is the weather today?", "Set a reminder at 10 A.M tomorrow for a meeting", "How far is Columbus from my location?", "Call Home" etc.

The current flow of the listener is that it initially waits for the user's speech (i.e., onReadyForSpeech (Bundle params)) and when the speech input arrives it starts capturing

it (i.e., onBeginningOfSpeech ()). Then, after the user stops speaking (i.e., onEndOf Speech ()), the audio input is sent to the servers to perform speech recognition and the recognition results are displayed as and when they are ready (i.e., onResults (Bundle results)). On the other hand, if there is no speech at all then the listener gives an error, thus, displaying an error message.

This flow is shown clearly in the following figure:

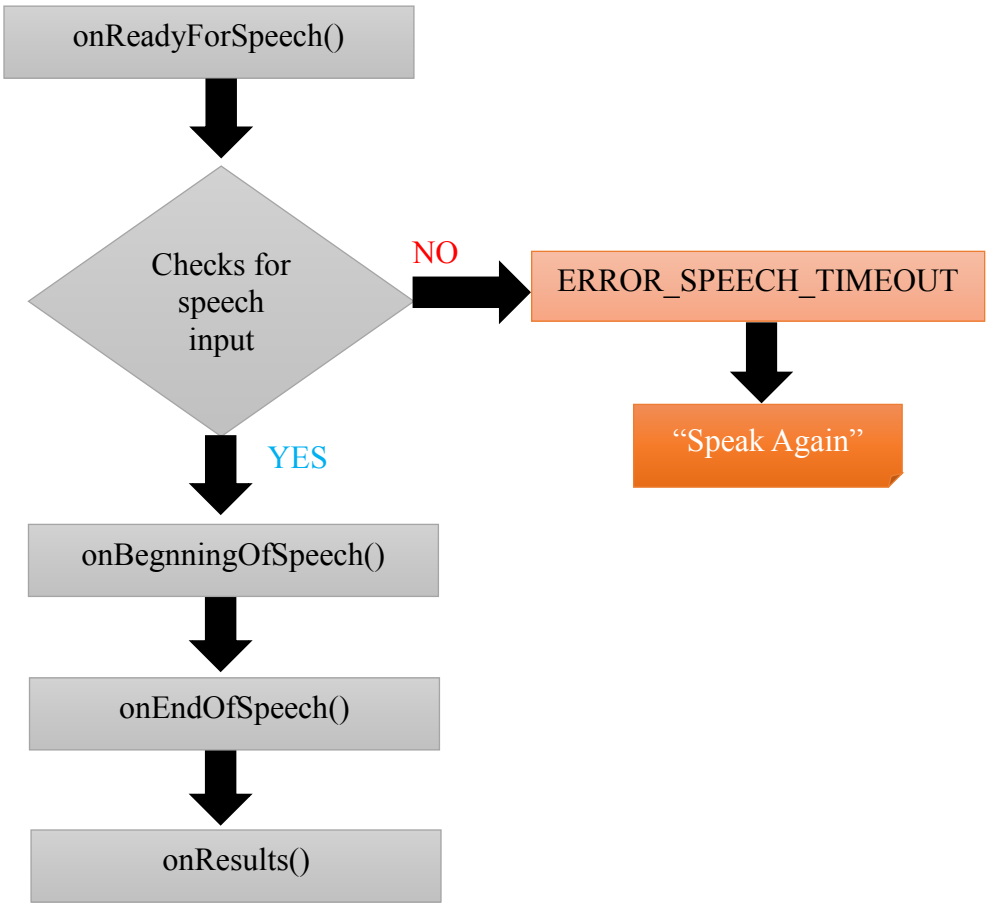


Figure 26: Flow chart for current flow of listener

For a speech recognizer to support a conversation rather than a question in a motivational Interviewing setup, where for example, doctors and patients speak for about 30 minutes, the current functionality of the speech recognizer had to be enhanced. In other words, the listener had to listen continuously for speech even after several pauses in a conversation. So, I have changed the flow of the listener in a way that supports the goal I want to achieve here.

Now, the flow of the listener is that it initially waits for the user's speech (i.e., onReadyForSpeech (Bundle params)) and when the speech input arrives it starts capturing it (i.e., onBeginningOfSpeech ()). Then, after the user stops speaking (i.e., onEndOf Speech ()), the audio input is sent to the servers to perform speech recognition and the recognition results are displayed as and when they are ready (i.e., onResults (Bundle results)) and the listener is again set to the initial state which is onReadyForSpeech (Bundle params). This change in the flow of the listener helps in continuing the recognition process even after a pause in the user's speech. On the other hand, if there is no speech at all then the listener again sets itself ready for any incoming speech in the future instead of giving an error.

From our observations, we have seen that the listener waits for 5 secs approximately to see if there is any speech input from the user, before going to the SPEECH_TIMEOUT error. If there is no speech input, then the listener goes back to listening state by starting a new intent in 0.2 secs approximately. Once it receives the input within this 5 secs time, it successfully converts the speech and displays the script on the screen and goes back to listening state again by starting a new intent in less than 0.2 seconds-0.4seconds.

This enhanced flow is shown clearly in the following figure:

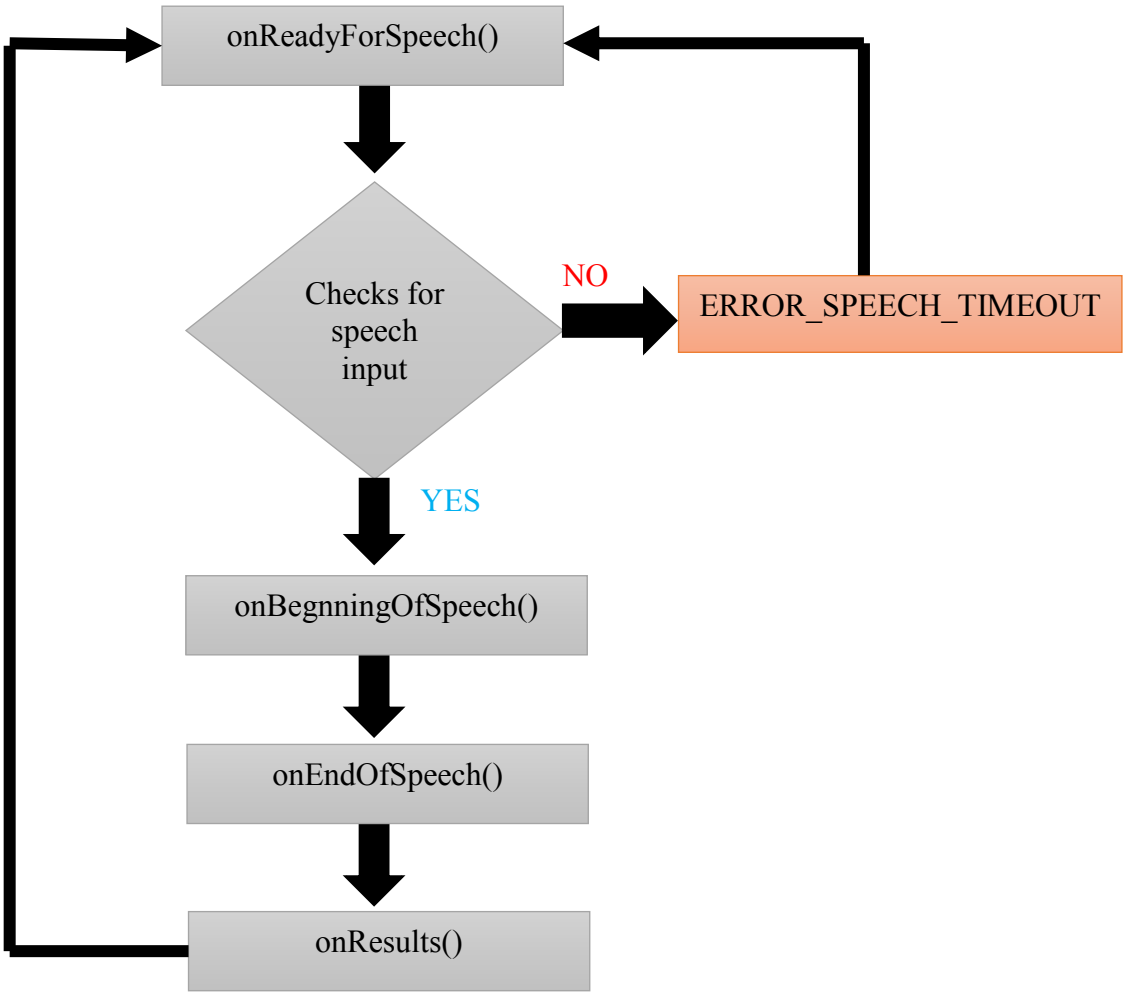


Figure 27: Flow chart for enhanced flow of listener

### 3.5 Design implemented for supporting Voice Recognition (Two-device design)

The android speech recognition API has the ability of converting the speech into text but doesn't support voice recognition which means recognizing or identifying the speaker's voice. The prototype of the android app that we have developed is used for analyzing the performance of the doctors being trained for motivational interviewing. For this analysis, it is necessary to differentiate the doctor's voice from the patient's voice.

Since the API used in the development of this system doesn't support the voice recognition feature, we used two android devices to capture doctor's voice on one and patient's voice on the other. Thus, the two-device design is used in order to support voice recognition capability.

The two devices communicate with each other using Bluetooth. Bluetooth allows a device to wirelessly exchange data with other Bluetooth devices within short range. The android Bluetooth APIs provide the Bluetooth functionality to perform the following operations:

- Scan for other Bluetooth devices
- Get a list of paired devices by querying the local Bluetooth adapter.
- Establish a channel of communication
- Connect to other devices through service discovery

The process for establishing communication is summarized below:

One device, is set to discoverable mode to allow other devices in the vicinity to send connection requests. Another device initiates a service discovery process to find the discoverable device. Only after the pairing request is accepted by the discoverable device, the two devices complete a bonding process where the security keys are exchanged. These keys are cached by the devices for later use. Once the pairing and bonding processes have occurred, the two devices can exchange information. On completion of the session, the device which initiates the pairing request releases the channel which was used to link it to the discoverable device. Once the manual connection is established, the two devices remain bonded, however, so they can interact automatically without user intervention each time they are in range of one another [18].

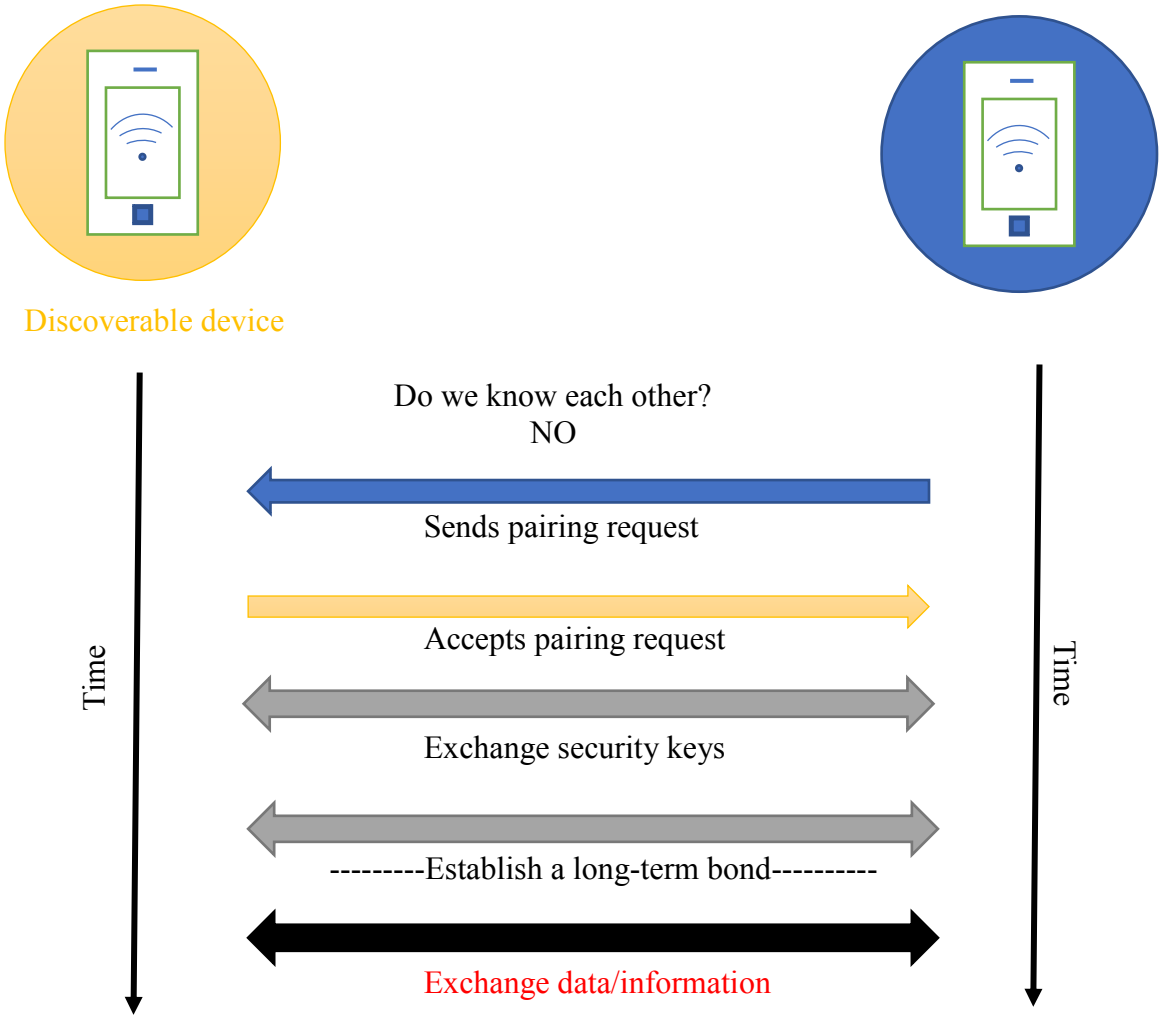


Figure 28: Process of pairing two Bluetooth devices

The application is installed on both the devices so that one device can be used to capture the doctor's part of the conversation and acts as the master device while the other device is used to capture the patient's part and acts as the slave device. After this installation, the two devices are connected to each other through Bluetooth. The master device is used to control the operations such as start, pause, stop and reset on the slave device. We implemented the functionalities of the Bluetooth API to send the doctor's script to the patient's device and vice versa while the conversation is in progress, instead of exchanging the full script after the conversation has ended.

## 3.6 Improving the efficiency of the System Design

Latency can be defined differently in different contexts. The basic meaning of latency is the time interval between the input into the system and the corresponding output expected. In our system design the input is the speech and the output to be generated is the transcription of the speech into text. To improve the efficiency of our system design we need to make sure that there is no significant latency between the background processing of speech and the foreground display of text (i.e., the User interface (UI)). There are 3 ways for displaying the text to the user on android devices. Those are: TextView, ListView and RecyclerView.

**TextView:**

It is a subclass of View and is used to show text to the user. The output of the latest speech input is just appended to the previous results. It is the simplest of all and gives efficient results with no latency in displaying the results.


Figure 29: TextView

**ListView:**

It is a view group that shows item in vertical scrollable list. An adapter, that pulls content from an external source, is used to populate the ListView.

An adapter in android acts as a bridge between UI components (i.e., AdapterView) that display the data and underlying data. The android framework provides developers with a set of native adapters such as ArrayAdapter, CursorAdapter etc that can be used or the developers can create their own custom adapters that best suits their requirement. ArrayAdapter is used for data based on arrays whereas the CursorAdapter is used for database related data.

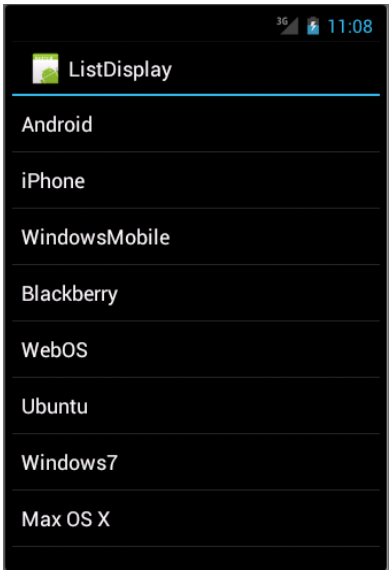


Figure 30: ListView

**RecyclerView:**

It is flexible and efficient version of ListView and is optimized to work with larger datasets. The RecyclerView widget can be used for data collections whose elements change based on user actions at runtime. It is found in the latest support-v7 version. Some advantages of RecyclerView are listed below:

- By default, it reuses cells while scrolling which could also be implemented in a ListView but was never a compulsion.
- LayoutManager feature allows the developers to dynamically change the layout to horizontal, vertical, grid or staggered grid while the ListView allowed just the vertical view.
- Animating the views and decorating the items has become easy with RecyclerView.
- It is much more customizable than the ListView.

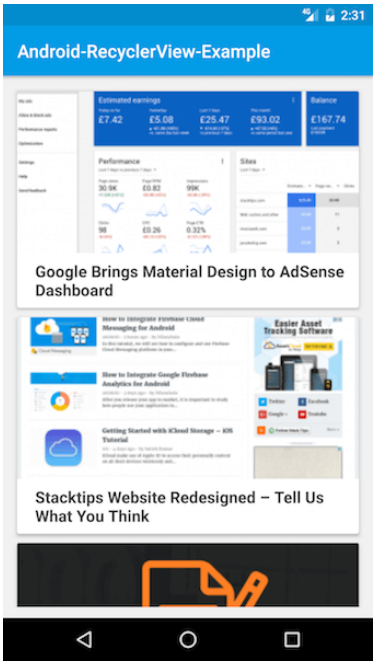


Figure 31: RecyclerView

We want the interference between the background processing of speech to text and the UI processing of displaying the text on screen, to be as minimum as possible. This is because there are chances of missing few words due to this latency which is not desirable for our system design.

Initially, we worked with TextView which gave efficient results with almost zero latency but the script was not organized properly which is why we then chose to work with

ListView. ListView is organized way of showing items in scrollable lists but the downside of using it is its performance. We observed that, for lengthy conversations, few words were missed because ListViews are not memory-efficient. They call findViewById() method for every child of our item layout and this process repeats for every getView() call. All this can become very processor-intensive causing the ListView scrolling to be non-responsive as it tries to gather references to the views we need while we scroll [19].

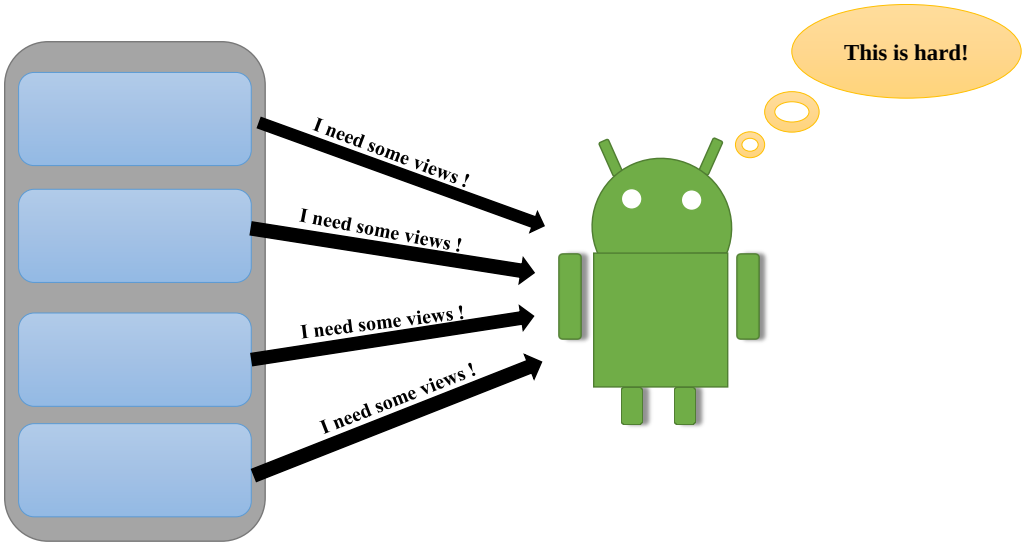


Figure 32: Problem with ListView

The solution to this problem was using the RecyclerView. Its main idea is to provide listing functionality in a performance-friendly manner. The RecyclerView overcomes the above-mentioned problem faced using the ListView by recycling items with the help of a pattern called View Holder. ListView also provides implementation of ViewHolder pattern but is optional whereas in RecyclerView it is mandatory. There is no need to call findViewById() method each time we go through the getView() method of our adapter with the usage of ViewHolder. The references to all the views are kept in memory,

thus, increasing the performance significantly. The only disadvantage of RecyclerView is its complexity. Thus, with all these advantages we have chosen to use RecyclerView to display the conversation of the doctor and the patient in the development of our app [20].

The other concern of the current two-device system design is the usage of the internal microphone. By default, the internal microphones of the devices will be used for capturing speech. Since the devices are close to each other, there are chances for the doctor's device to capture the patient's voice and vice-versa. So, one way for capturing speech efficiently would be holding the devices and talking directly to the internal microphones. This minimizes the flexibility of the model. Therefore, to make the system design more flexible and efficient, we have used two directional Bluetooth microphones that can be clipped to the person's clothing. One of the microphone is connected to the doctor's device and the other is connected to the patient's device.

The overall system design is as follows:

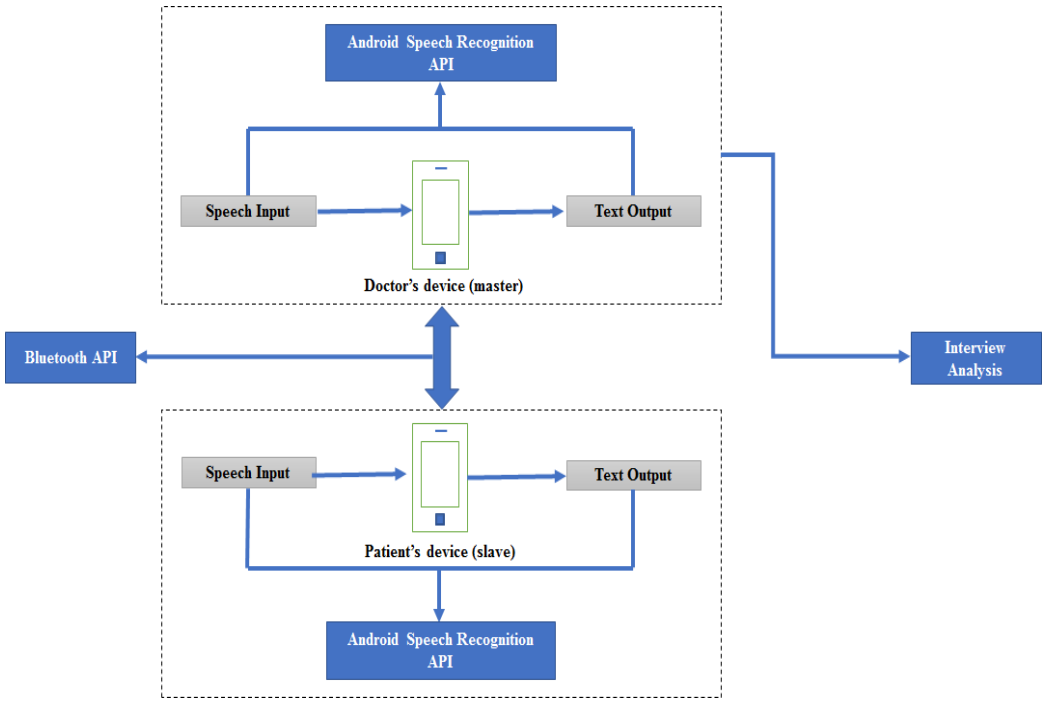


Figure 33: Implemented System Design

# CHAPTER 4

## 4.1 Interview Analysis

The functionality of the app developed as a part of this thesis can be divided into two parts. The first part focusses on conversion of speech to text while the second part focusses on analyzing the overall interview. So far, we have discussed about the first part in the previous chapters. Therefore, in this chapter we will discuss more about the interview analysis.

The interview analysis gives an instant summary of the performance of the doctor who is being trained for MI in real-time. This summary includes number of open-ended and close-ended questions asked by the doctor. It also gives the total amount of time spoken by the doctor, the amount of time spoken by the patient and the total duration of the interview.

In addition, our app also provides full scripts of the interviews, a list of open questions, a list of close questions. This analysis helps the trainers know where a trainee stands and it also helps the trainees know where they are lagging, which would in turn help them improve their performance next time. The app also provides the option of saving the interview analysis so that the trainers can keep a track of a trainee's performance over time.

Two important measures for an interview to be considered as a good interview are:

- Number of open-ended questions should be greater than the number of close-ended questions because open-ended questions encourage the patient to express his/her feelings.
- Percentage of time spoken by the doctor in an interview should be less than the percentage of time spoken by the patient because the overall goal of MI is to get the patient talk towards change.

Thus, if more open-ended questions are asked then the patient ends up talking more which is a positive sign for an interview to end up as a good interview.

The logic/grammar that we have implemented for determining open-ended and closed ended questions can be improved by various other NLP (Natural Language Processing) techniques.

Table 8: List of different Keywords

| | |
|---|---|
| List of Keywords for open-ended questions | What, How, Why, Where, When |
| List of keywords for close-ended questions | Did, Shall, Are, May, Is, Should, Will, Might, Could, Can, Were, Would, Does, Have, Do |

For now, our implementation analyzes just the doctor's script for open-ended and close-ended questions at the end of the interview.

- The text result is trimmed such that the coordinating conjunctions such as "and", "but", "nor", "so", "yet" and the words that appear before it are removed.

For example, "**So** what did you eat yesterday" becomes "what did you eat yesterday".

This helps in identification of open and close keywords during further analysis described below.

This modified text undergoes further analysis:

STEP 1: If the text starts with an open keyword, it is classified as an open-ended question and the control goes to step 5.

For example: "**What** made you decide to quit smoking when you were pregnant"

Otherwise, the control goes to step 2.

STEP 2: If the length of the text output is greater than 10 words then the paragraph is searched for an open keyword. This is because we would not want to miss any of the open-ended questions asked by the doctor. If an open keyword is found, then the paragraph is classified as an open-ended question and the control goes to step 5.

For example: "Sure and it sounds like you are trying not to smoke around him **why did you make that decision**"

Otherwise, the control goes to step 3.

STEP 3: If the text starts with a close keyword then it is classified as a close-ended question and the control goes to step 5.

For example: "**Are you** smoking"

Otherwise, the control goes to step 4.

STEP 4: If the length of the text is greater than 10 words then the paragraph is searched backwards for any close keywords followed by the word "you". This is because

from our observations, the doctor asks a question in the end after giving feedback to the patient on his previous reply. Also, usually in most cases from our observations, a close keyword is followed by the word "you". Thus, if such a pattern is observed then it is classified as a close-ended question and the control goes to step 5.

For example: " I really need you to quit smoking both for your health and for Eden smoking around your child is associated not only with ear infections it could get to the point where you have to put tubes in his ears pretty shortly here also things like vitamin c deficiency, cavities like dental cavities, behavior problems, asthma, other upper respiratory infections its really putting him at a lot of risk in addition to that kids of smokers end up smoking themselves **do you want him to grow up to be a smoker**"

STEP 5: The next text result is selected for the analysis.

Our implementation gives priority to the open questions than the close questions during interview analysis. Therefore, we first check for any open keywords before checking for the close keywords. Analyzing the text for open or close questions is not easy because there are no punctuations used in the process of conversion of speech to text. Punctuations are used only when they are read out explicitly.

For example: "Well **comma** one of the primary risk factors for multiple ear infections in kids is actually smoke exposure **full stop** Are you smoking **question mark**.

But in a conversation the speakers will not be saying such punctuations and thus, differentiating various sentences is not possible. Hence, the above-mentioned real-time

analysis has been applied for capturing open and closed-ended questions instantly. A flow chart summarizing the same procedure for analysis is given in the next page.

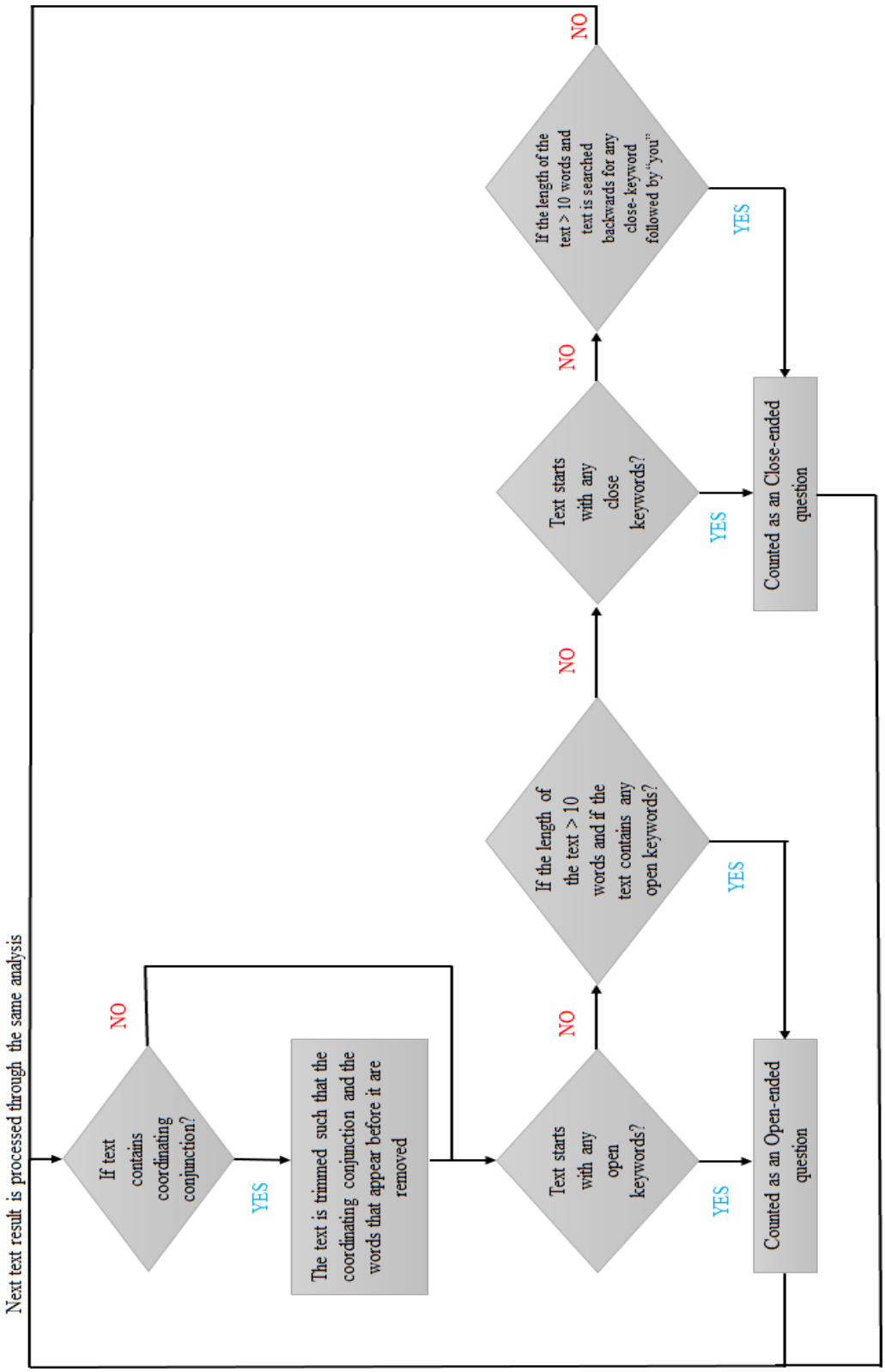


Figure 34: Flow chart for grammar analysis

## CHAPTER 5

### Experimental results

In this chapter, we have included few screenshots of the results obtained.

SCREENSHOT 1: It is the homepage of the tablet (i.e., Google Nexus 7) which was used to install and run our application. As seen from the screenshot, the MI app is displayed on the homepage once installed.

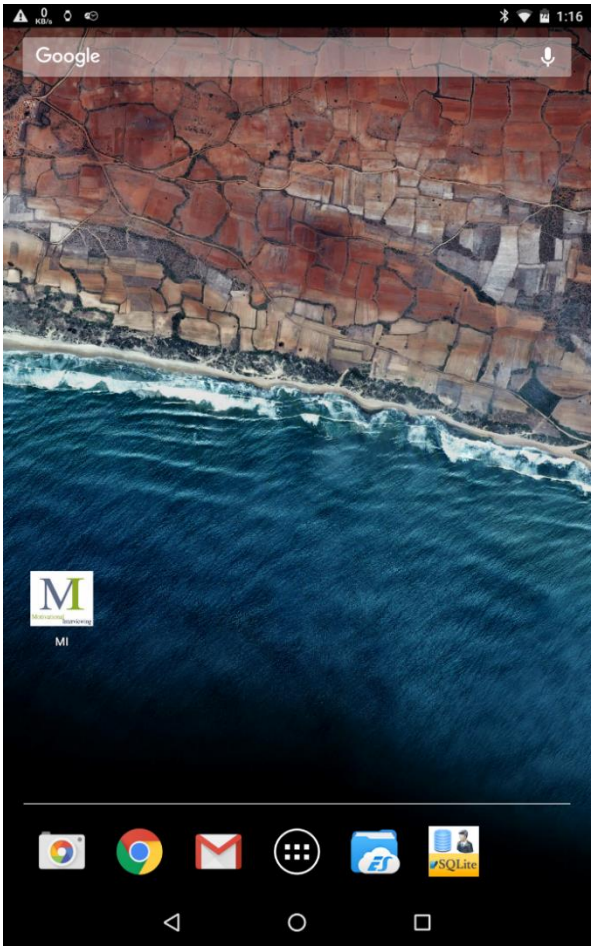


Figure 35: SCREENSHOT 1

SCREENSHOT 2: This shows the first page of the application. The participants select their roles to navigate to their respective page.

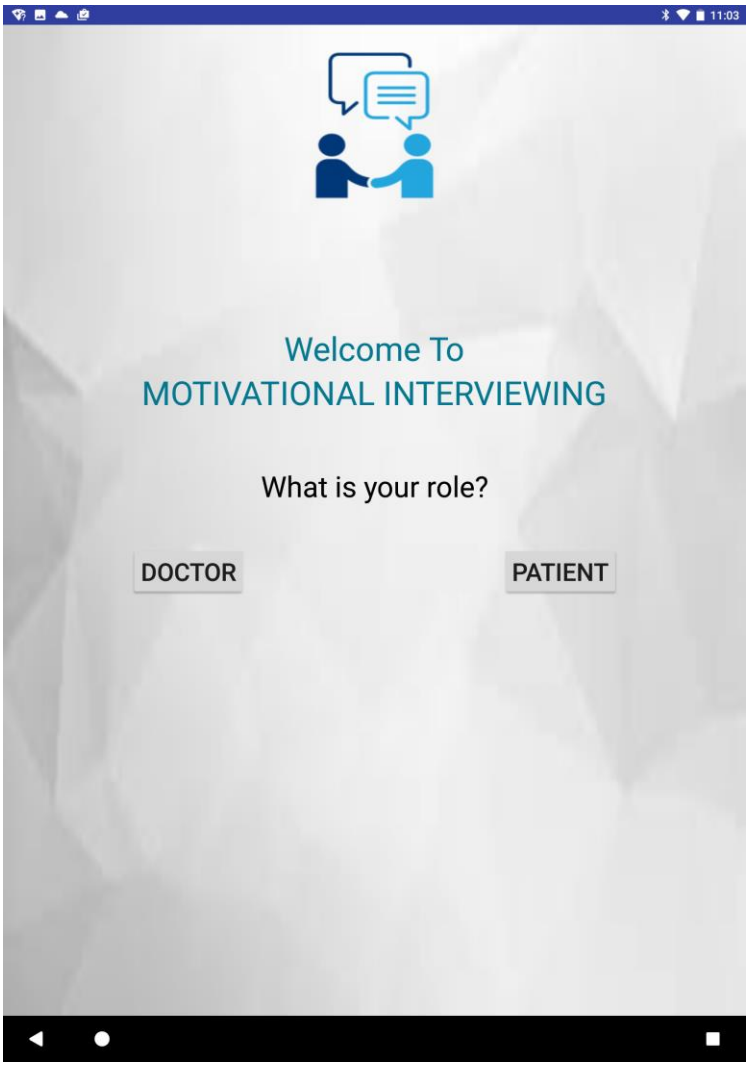


Figure 36: SCREENSHOT 2

SCREENSHOT 3: If “DOCTOR” is the role selected then this dialog box appears which prompts to enter the name. This is because at the end of the interview, the analysis can be stored with this entered name, and is appended by date and time. It helps the trainers in seeing the progress of a trainee over time during the training for motivational interviewing.

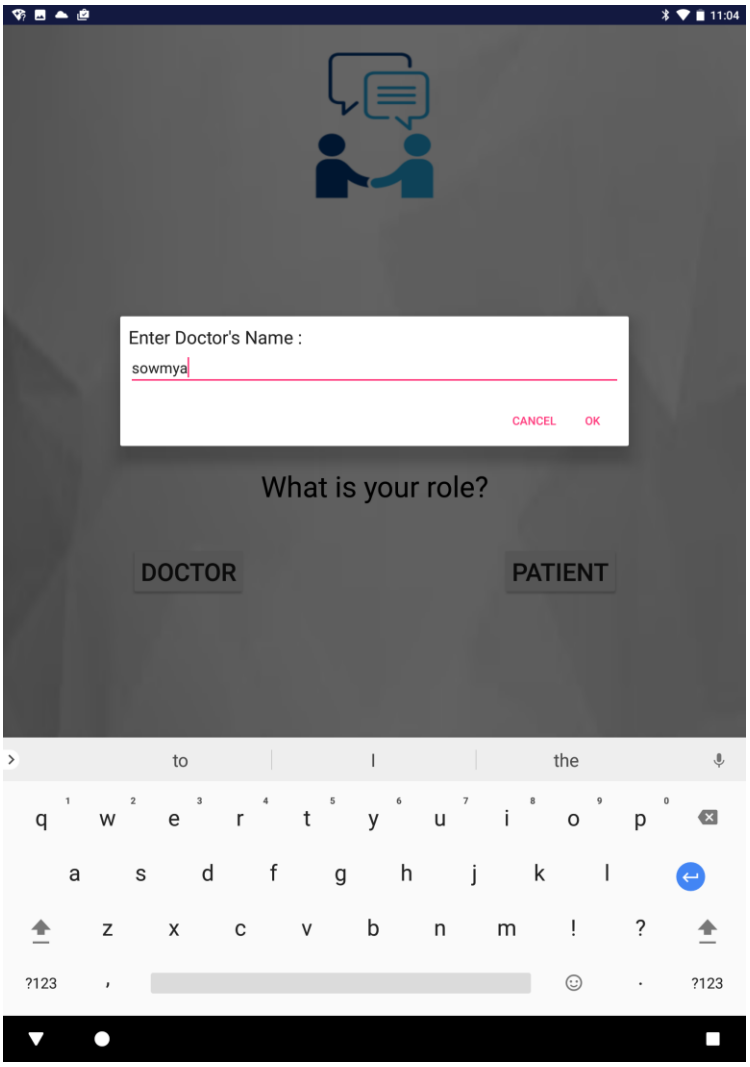


Figure 37: SCREENSHOT 3

SCREENSHOT 4: This is a screenshot showing the home page of the participant whose selected role is “DOCTOR”.

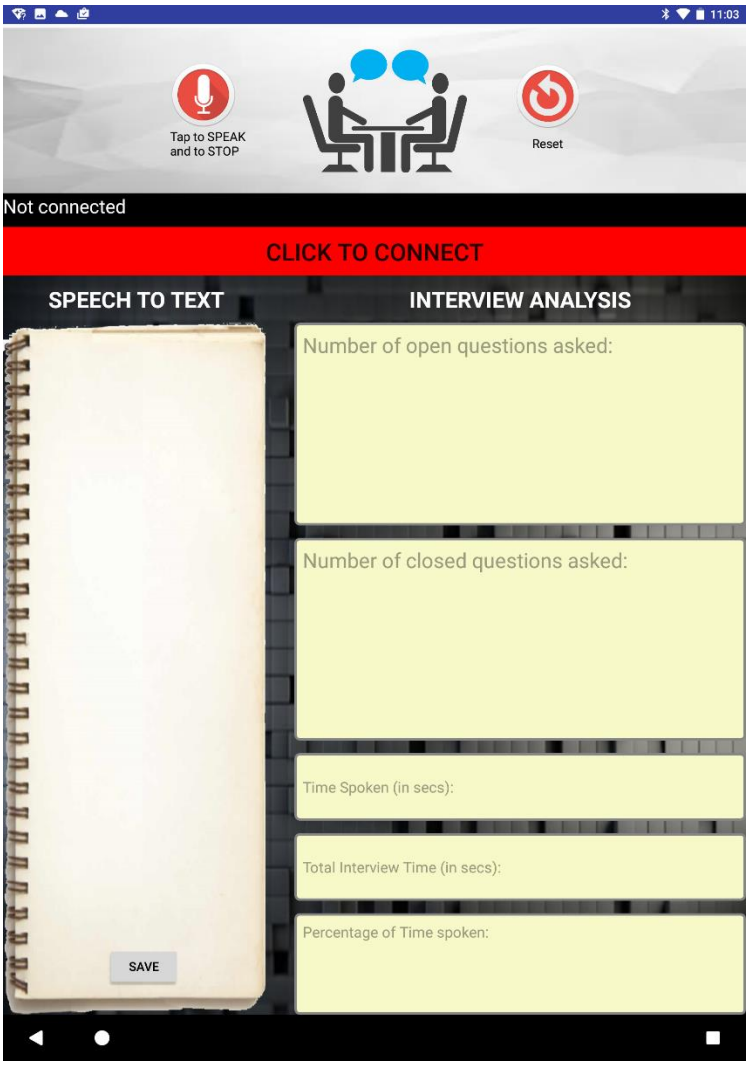


Figure 38: SCREENSHOT 4

SCREENSHOT 5: This is a screenshot showing the home page of the participant whose selected role is “PATIENT”.

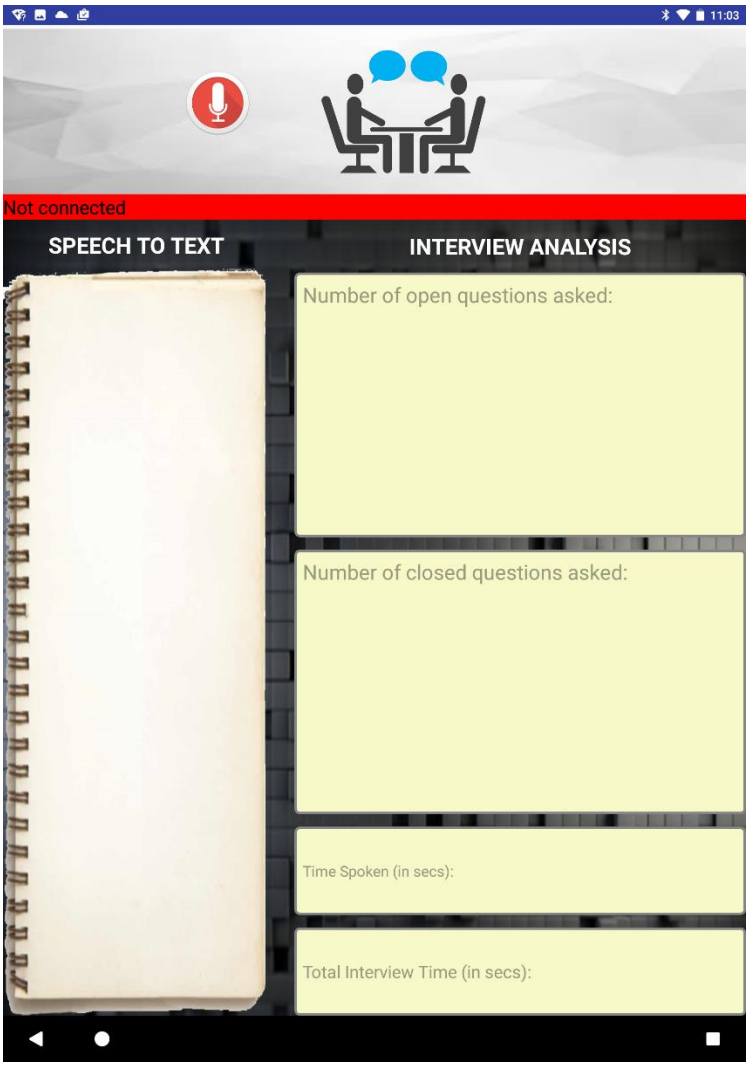


Figure 39: SCREENSHOT 5

SCREENSHOT 6: Before starting the conversation or interview, both the devices must be connected like described in chapter 3. The dialog box shown in the screenshot below appears after the user clicks on the “CLICK TO CONNECT” button on the master device (i.e., doctor’s device). The dialog box shows 2 lists. One is the list of paired devices and the other is the list of discovered devices. Connection is established between the 2 devices after selecting a slave device (i.e., patient’s device) from the paired devices list.

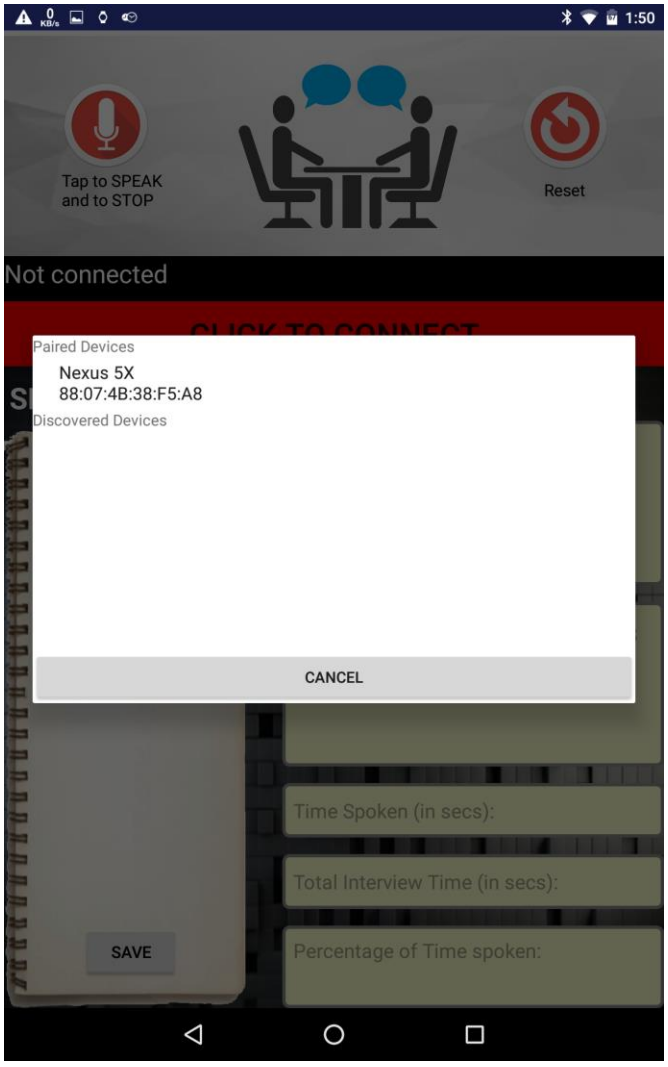


Figure 40: SCREENSHOT 6

**TESTING THE APPLICATION WITH AN EXAMPLE OF A GOOD INTERVIEW**

SCREENSHOT 7: After connecting the two devices via Bluetooth, the interview/conversation can be started by clicking the "Tap to SPEAK and to STOP" button on the master device which would start recording the doctor's speech. This action performed on the master device is sent via Bluetooth to the slave device, thus, starting the same button on the slave device which would start recording the patient's speech simultaneously. As evident from the screenshot, the conversation between the doctor and the patient is successfully converted to text and is displayed in the designated area on the screen. These are the screenshots of the doctor's screen.

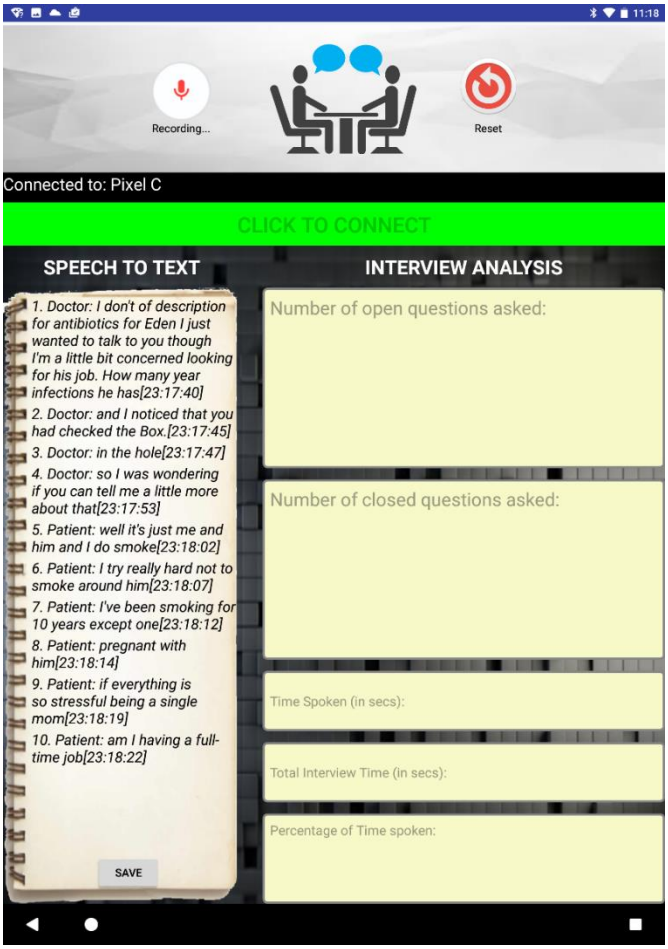


Figure 41: SCREENSHOT 7

SCREENSHOTS 8 and 9: The screenshots of the doctor's screen showing the on-going progress of the conversation.

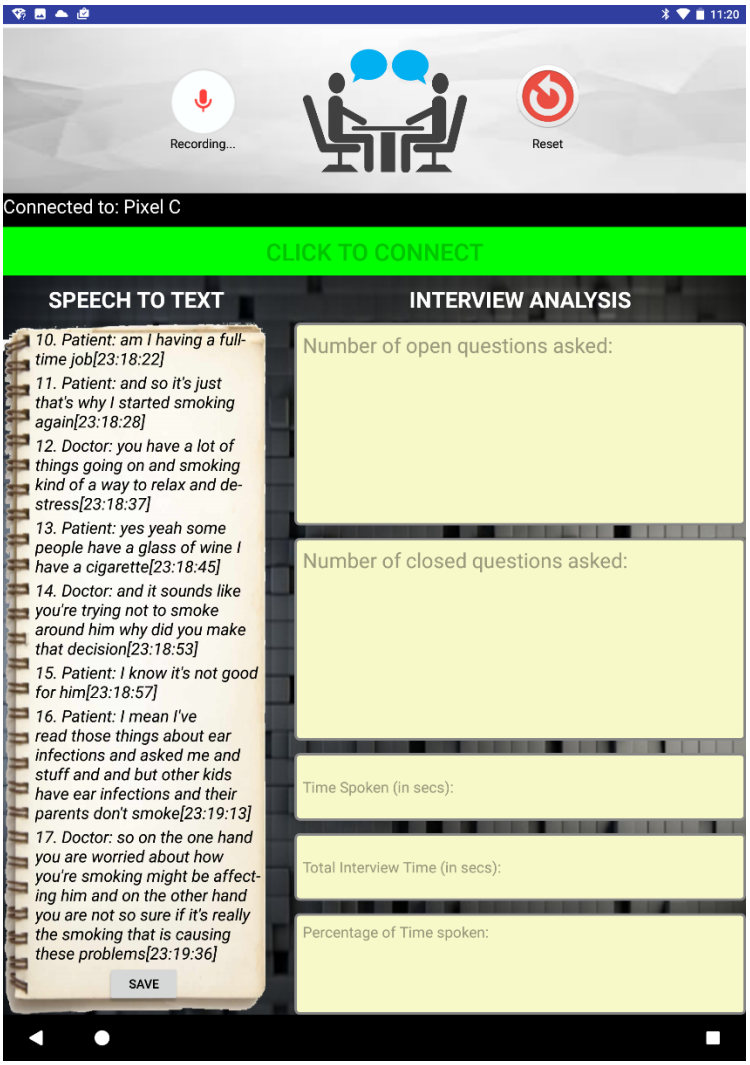


Figure 42: SCREENSHOT 8

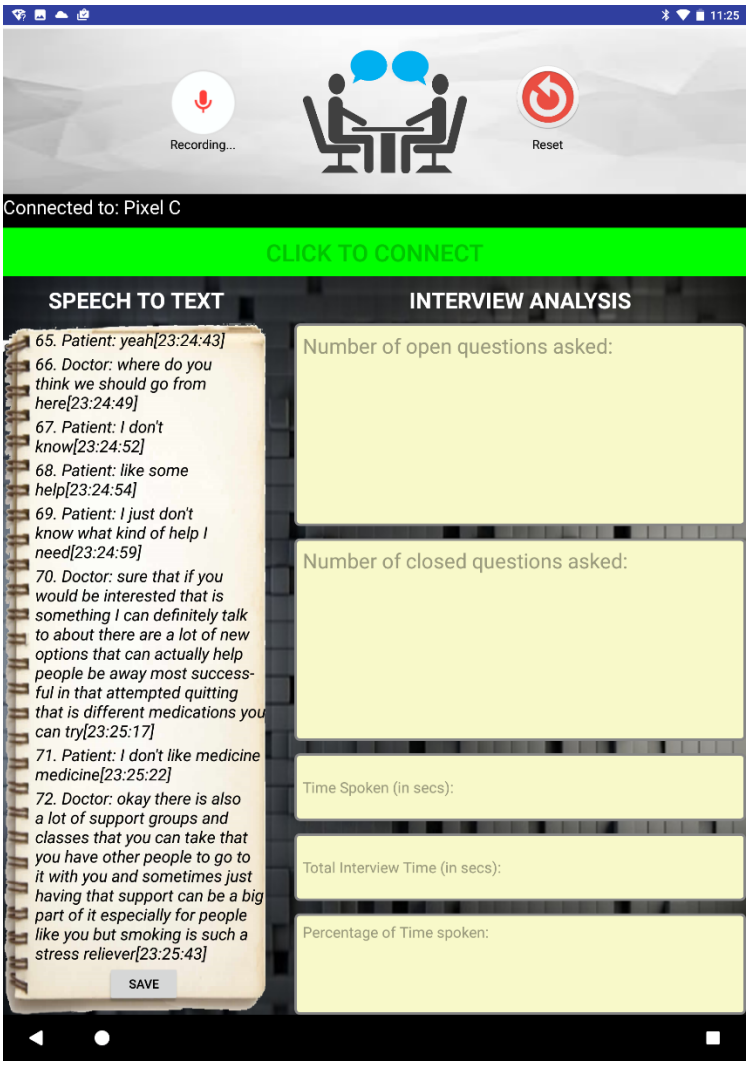


Figure 43: SCREENSHOT 9

SCREENSHOT 10 and 11: After the user stops recording the conversation by clicking on the “Tap to SPEAK and to STOP” button again, the analysis of the total interview so far recorded is displayed as shown in the screenshot below. The analysis shows that the doctor has asked about 7 open-ended questions and 0 close-ended question in the entire interview. It also shows that the time spoken by the doctor, which is 168 seconds and the total interview time, which is 552 seconds. Thus, calculating the percentage as 40%, after receiving the time spoken by the patient. Depending on the analysis, it can be concluded that the interview is an example for a good interview because the doctor spoke for less than 50% of the time and also there were no close-ended questions asked.

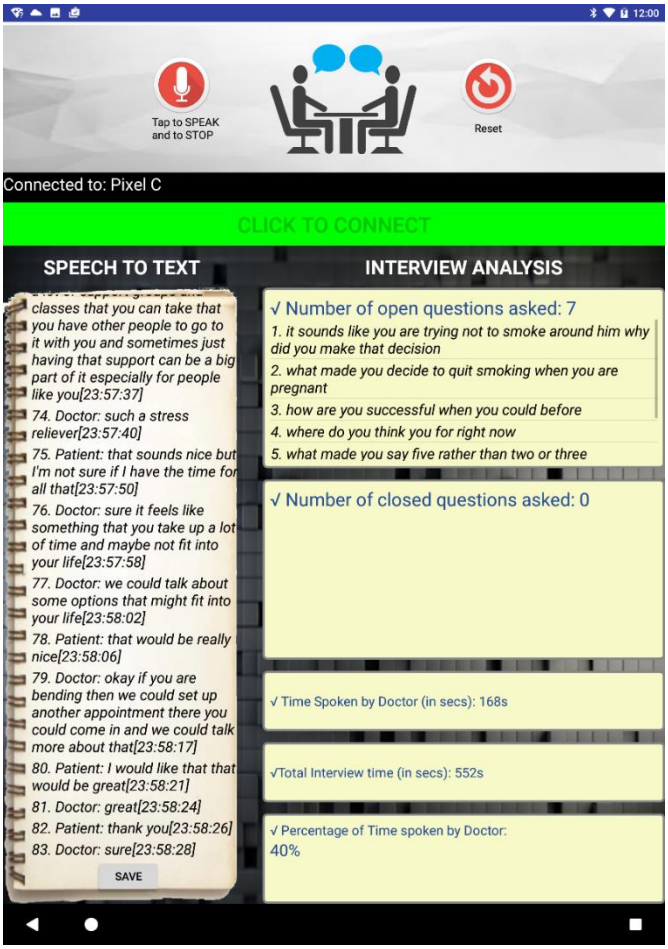


Figure 44: SCREENSHOT 10

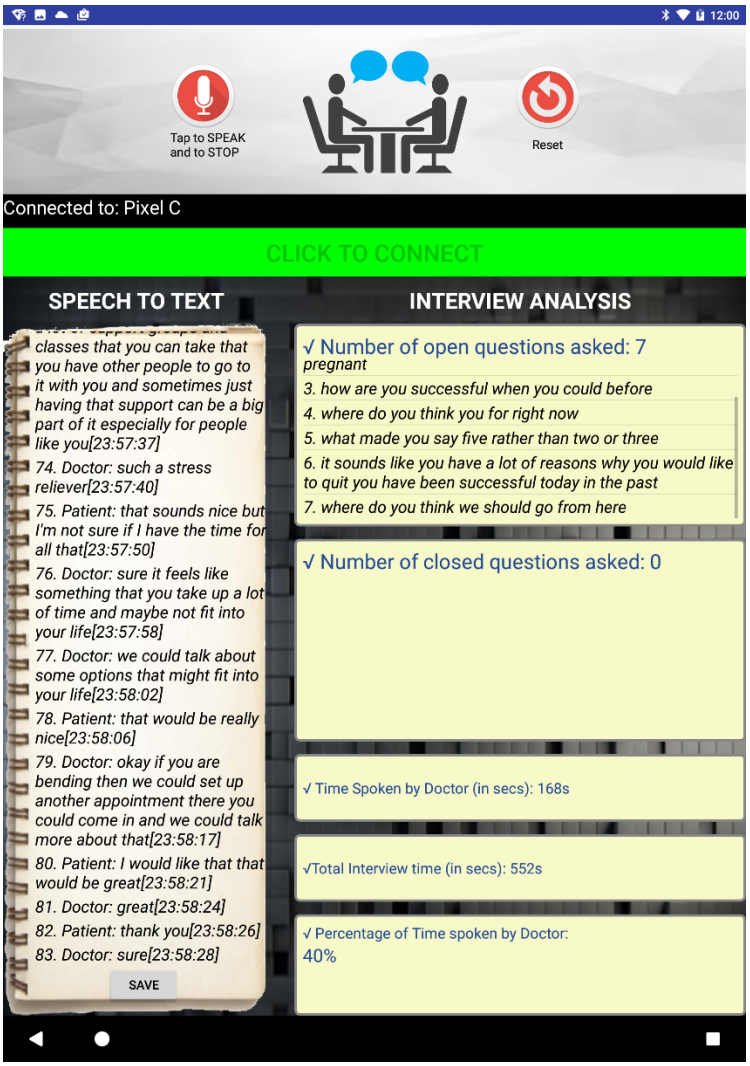


Figure 45: SCREENSHOT 11

SCREENSHOT 12: These are the screenshots of the patient's screen of the same interview shown in the above screenshots.

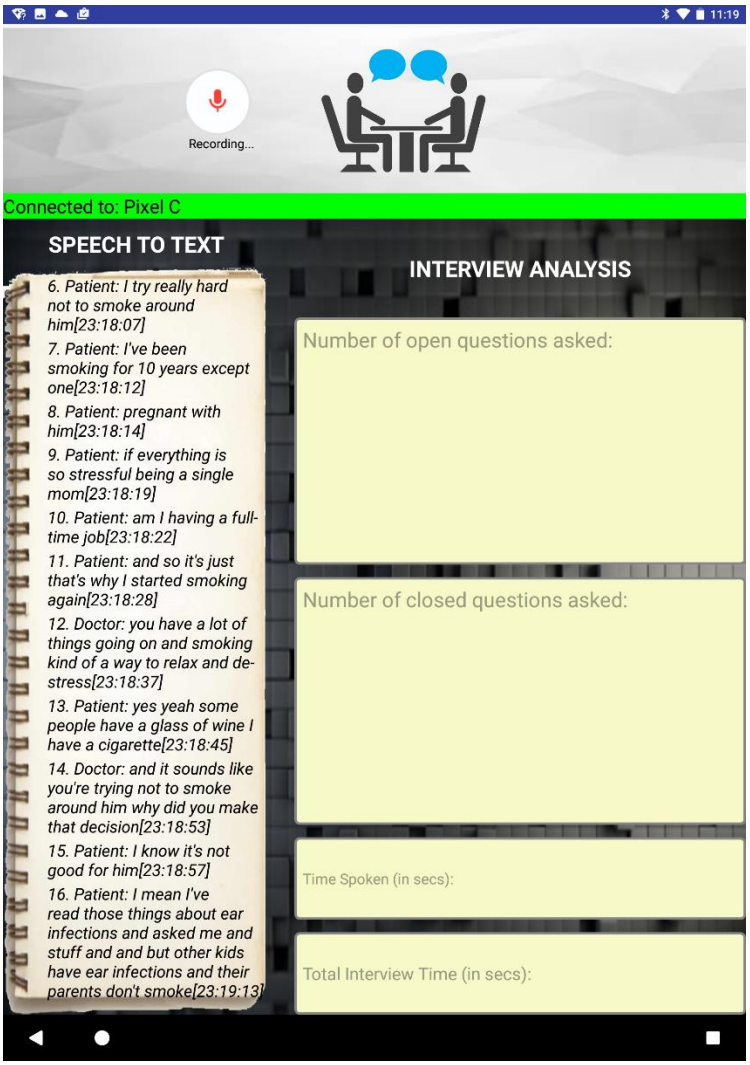


Figure 46: SCREENSHOT 12

SCREENSHOT 13: The screenshot of the patient's screen showing the on-going progress of the conversation.

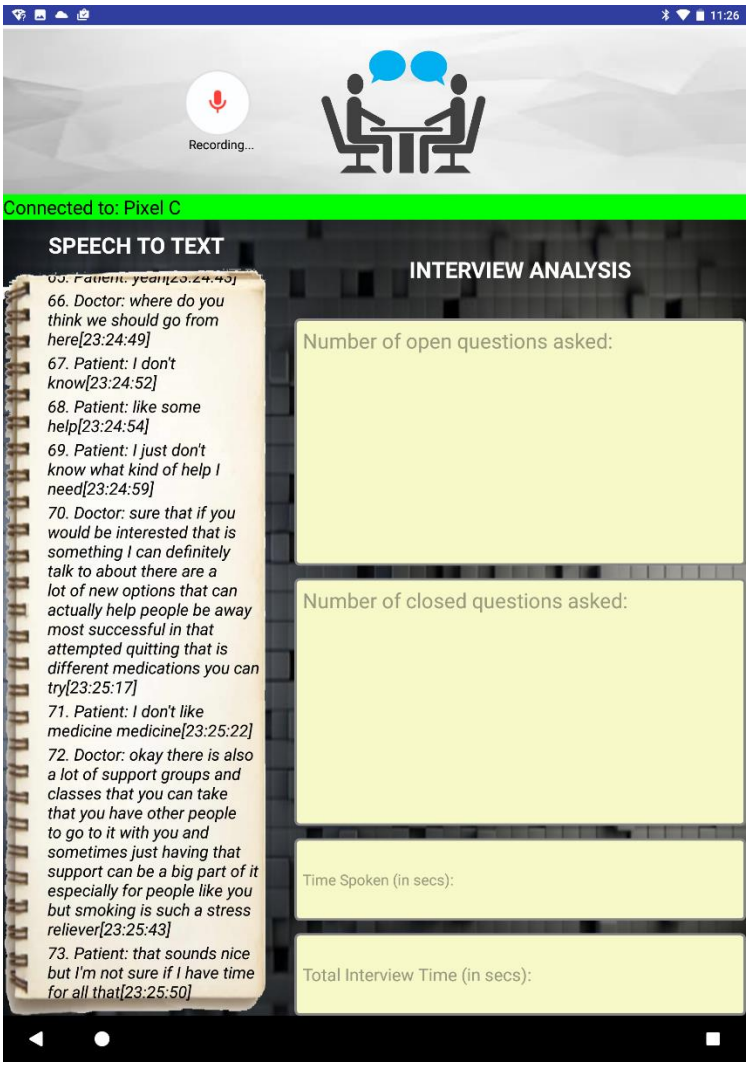


Figure 47: SCREENSHOT 13

SCREENSHOT 14: We do not analyze the patient's speech in our implementation and hence, as seen from the screenshot only the time spoken by the patient is calculated as 255 seconds and displayed along with the total interview time which is 552 seconds. The time spoken by the patient is used in the calculation of the percentage of time spoken by the doctor excluding the total time of silence in the interview.

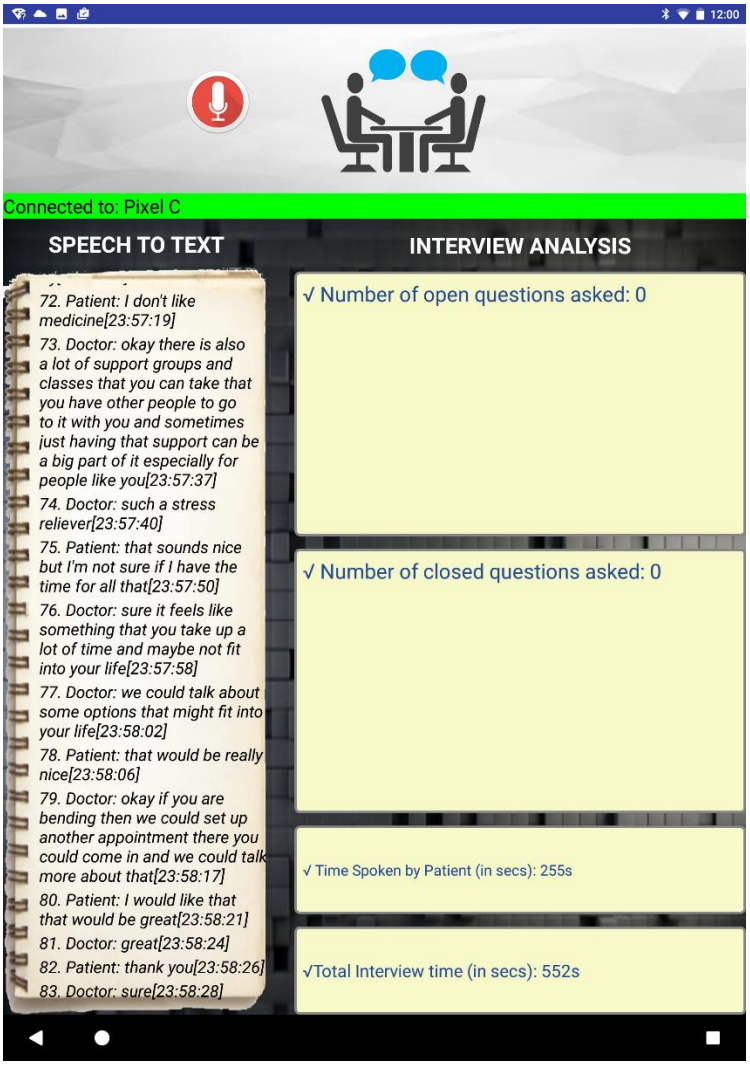


Figure 48: SCREENSHOT 14

The contents of the file that is saved after the completion of the interview is shown here:

**INTERVIEW ANALYSIS**

**----------**

**Open Questions are:** 7

1) It sounds like you are trying not to smoke around him why did you make that decision

2) What made you decide to quit smoking when you are pregnant

3) How are you successful when you could before

4) Where do you think you for right now

5) What made you say five rather than two or three

6) It sounds like you have a lot of reasons why you would like to quit you have been successful today in the past

7) Where do you think we should go from here

**Closed Questions are:** 0

Time Spoken by Doctor (in secs): 168s

Time Spoken by Patient (in secs): 255s

Total Interview time (in secs): 552s

Percentage of Time spoken by Doctor: 40%

**INTERVIEW CONVERSATION**

---

**Doctor:** I know the prescription for antibiotics for Eden I just want to talk to you though I am a little bit concerned looking through his job.

**Doctor:** affections he has had recently

**Doctor:** I noticed that you had checked the box that someone smoking in the home

**Doctor:** so I was wondering if you can tell me a little more about that

**Patient:** well it's just me and him

**Patient:** I do smoke

**Patient:** I tried really hard not to smoke around him but I've been smoking for 10 years except when I was pregnant with him

**Patient:** it everything is so stressful being a single mom and my having a full-time job and

**Patient:** just that's why I started smoking again

**Doctor:** you have a lot of things going on and smoke

**Doctor:** to relax and de-stress

**Patient:** yes yeah

**Patient:** we'll have a glass of wine I have a cigarette

**Doctor:** sharp and it sounds like you are trying not to smoke around him why did you make that decision

**Patient:** I know it's not good for him

**Patient:** I've read those things about ear infections and asthma

**Patient:** stop

**Patient:** back at the kids have ear infections and their parents don't smoke

**Doctor:** so on one hand you are worried about how your smoking might be affecting him and on the other hand you are not so sure if it is really the smoking that is causing these problems

**Patient:** Wright

**Patient:** I mean he doesn't have asthma

**Patient:** hasn't had a lot of other problems that his other friends have

**Patient:** and I have thought about quitting before in the past but I just don't I just don't see how it's possible right now

**Doctor:** what made you decide to quit smoking when you are pregnant?

**Patient:** well he was inside me and we were sharing everything

**Patient:** and I know that he will get some of that and I didn't I just didn't think I could live with myself if something happened to him

**Doctor:** right now it seems almost too difficult to even manage or even to try

**Patient:** yeah exactly

**Doctor:** how are you successful when you could before?

**Patient:** I don't know I think about it now and I don't even know how I did it

**Patient:** I just I just did it you know I just couldn't imagine like him not being born

**Patient:** going into labor early and him

**Patient:** problems and stuff like that all the stuff that they talked about woman who smoke

**Patient:** eye doctors just enough to say okay you know what I'm not going to risk that and so

**Doctor:** this was so scary then that you were able to stop but they don't feel a scary to you now

**Patient:** no I mean we are two separate people

**Patient:** like I said I don't I tried really hard not to smoke around him

**Patient:** pretty good about that

**Patient:** I'm glad other people smoke around him

**Patient:** oh you know

**Doctor:** you are doing the best you can do

**Patient:** yes

**Doctor:** okay but it sounds to me to like part of you really just want to quit

**Patient:** yeah

**Patient:** no. I need to and I know

**Patient:** every new USA okay this year I'm going to quit smoking but then something happens

**Patient:** just doesn't

**Doctor:** get those on your to-do list but it is just not making it to the top

**Doctor:** if you did decide to quit on a scale of 1 to 10 where one is not at all confident you don't think you could do it and 10 is you feel pretty certain that you could

**Doctor:** where do you think you for right now

**Patient:** probably like A5

**Patient:** find of an insured area

**Patient:** I know I've done it before so I know I can do it but at the same time

**Patient:** seems really hard

**Patient:** it's not the same situation

**Doctor:** what made you say five rather than two or three

**Patient:** I know I know all the ways it's bad for me

**Patient:** I don't want him to grow up thinking that it's okay to smoke

**Patient:** I don't want him

**Patient:** any kind of

**Patient:** you want him to chew or anything like that

**Patient:** I know I need to especially before he gets old enough to understand what Mommy is doing but I just don't know if I can do it

**Doctor:** okay so it sounds like you have a lot of reasons why you would like to quit you have been successful today in the past

**Doctor:** you are just feeling a little bit hesitant about your ability to do it

**Patient:** yeah

**Doctor:** where do you think we should go from here

**Patient:** I don't know

**Patient:** some help I just

**Patient:** what kind of help I need

**Doctor:** sure if you would be interested that's something I can definitely talk to about there are a lot of you options that can actually help people be way more successful in their attempt at quitting

**Doctor:** there is different medications you can try

**Patient:** I don't like medicine

**Doctor:** okay there's also a lot of support groups and classes that you can take that you have other people to go to it with you and sometimes just having that support can be a big part of it especially for people like you

**Doctor:** such a stress reliever

**Patient:** that sounds nice but I'm not sure if I have the time for all that

**Doctor:** sure it feels like something that you take up a lot of time and may be not fit into your life

**Doctor:** we could talk about some options that might fit into your life

**Patient:** that would be really nice

**Doctor:** okay well if you are bending then we could set up another appointment there you could come in and we could talk more about that

**Patient:** I would like that that would be great

**Doctor:** great

**Patient:** thank you

**Doctor:** sure

**TESTING THE APPLICATION WITH AN EXAMPLE OF A BAD INTERVIEW**

SCREENSHOT 15: As evident from the screenshot the conversation between the doctor and the patient is successfully converted to text and is displayed in the designated area on the screen. These are the screenshots of the doctor's screen. The "Reset" button is used to clear the contents of both the doctor's and patient's screen. Thus, the recording of the bad interview was started after clearing the screens on both the devices using the reset button.

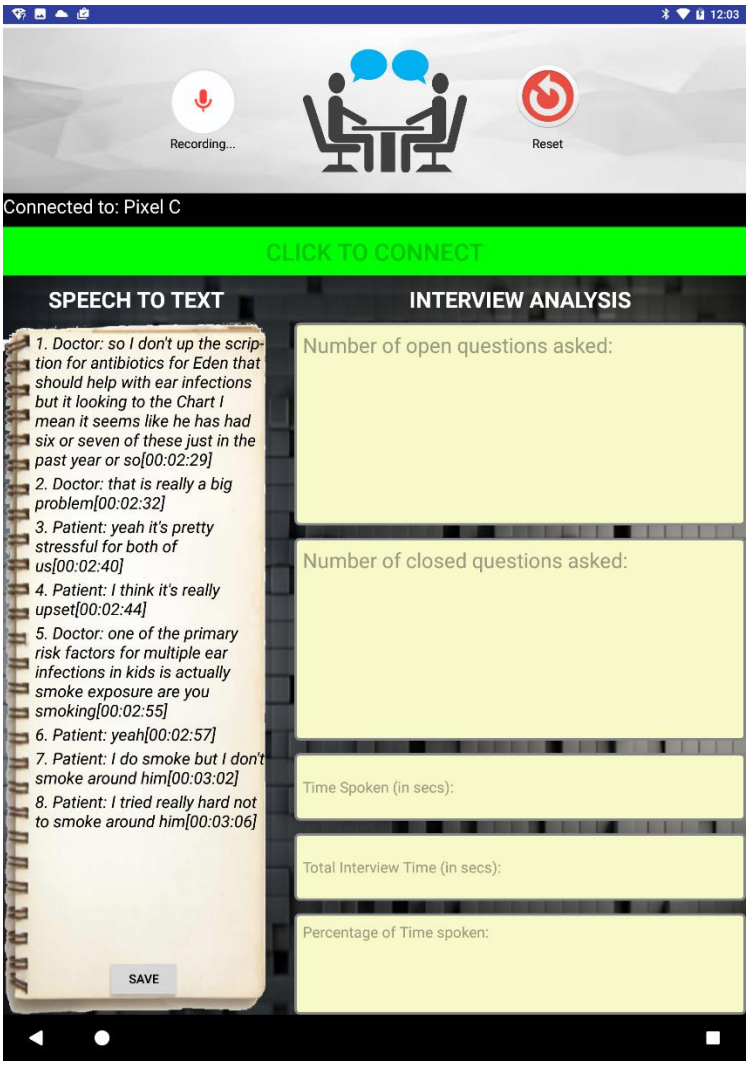


Figure 49: SCREENSHOT 15

SCREENSHOTS 16 and 17: The screenshots of the doctor's screen showing the on-going progress of the conversation.

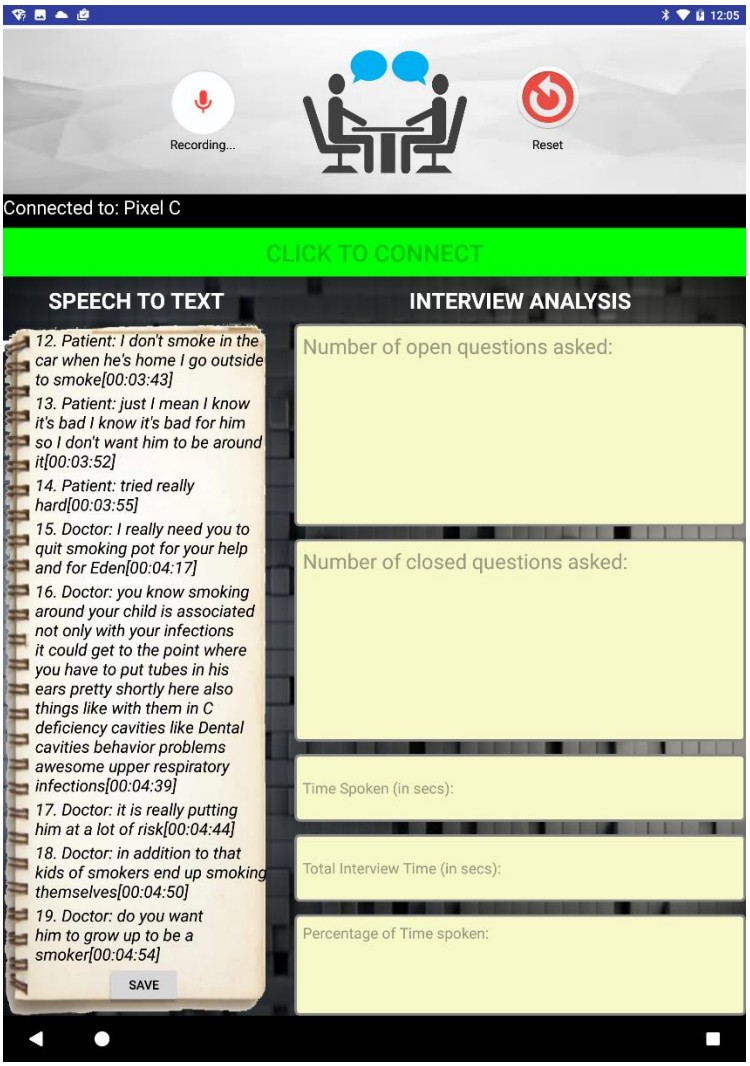


Figure 50: SCREENSHOT 16

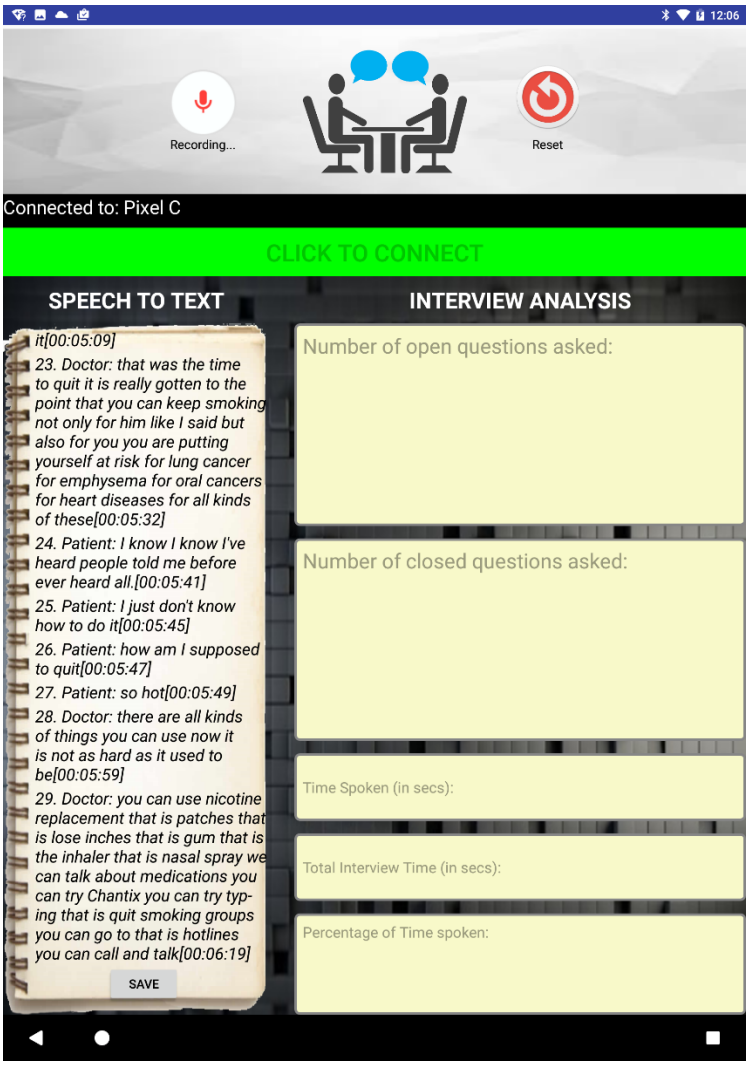


Figure 51: SCREENSHOT 17

SCREENSHOT 18: The analysis shows that the doctor has asked about 4 open-ended questions and 2 close-ended question in the entire interview. It also shows that the time spoken by the doctor, which is 129 seconds and the total interview time, which is 274 seconds. Thus, calculating the percentage as 59%, after receiving the time spoken by the patient. Depending on the analysis, it can be concluded that the interview is an example for a bad interview because the doctor spoke for more than 50% of the time.

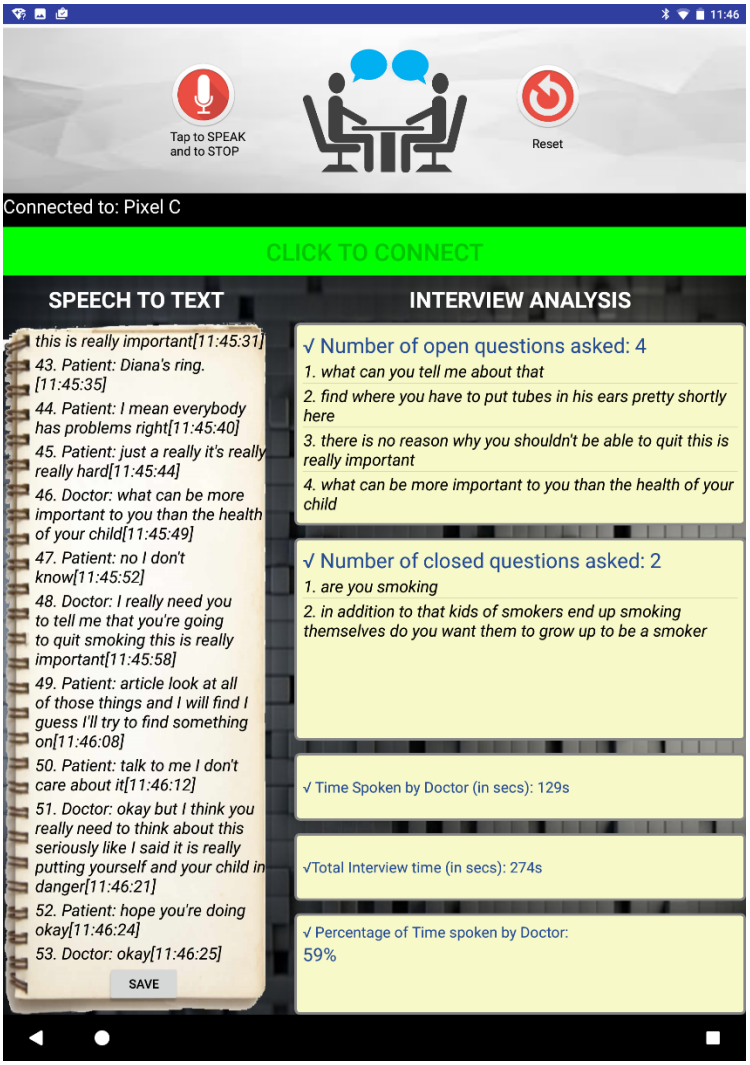


Figure 52: SCREENSHOT 18

SCREENSHOT 19: These are the screenshots of the patient's screen of the same interview shown in the above screenshots.

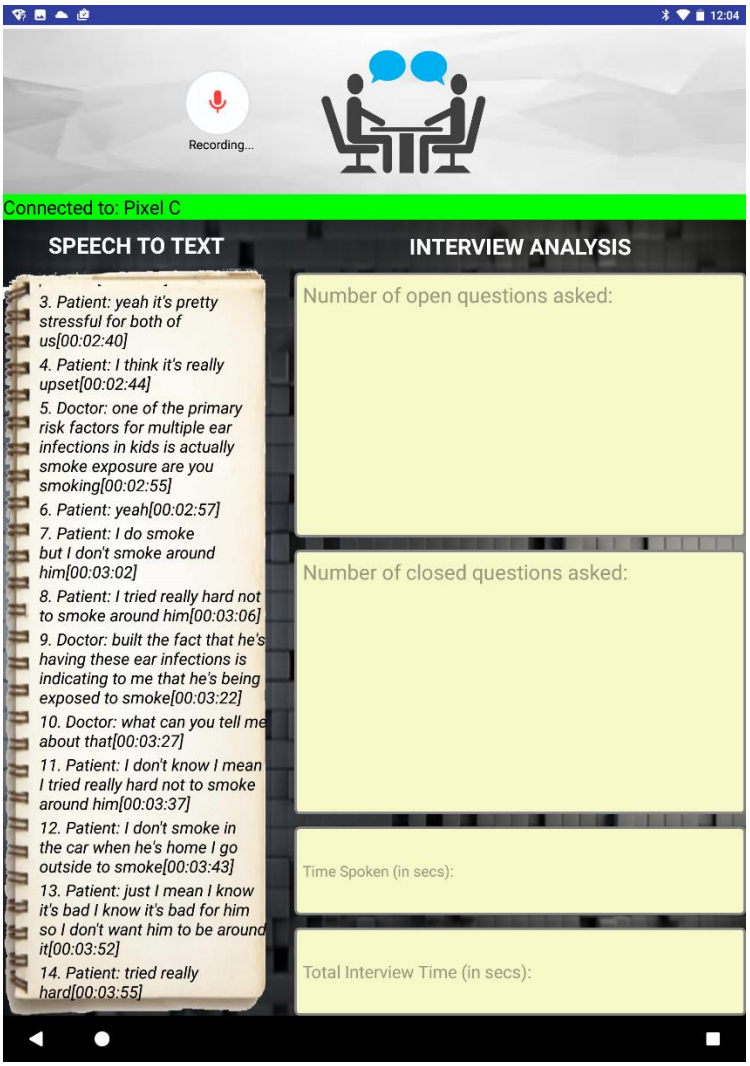


Figure 53: SCREENSHOT 19

SCREENSHOT 20: The screenshot of the patient's screen showing the on-going progress of the conversation.

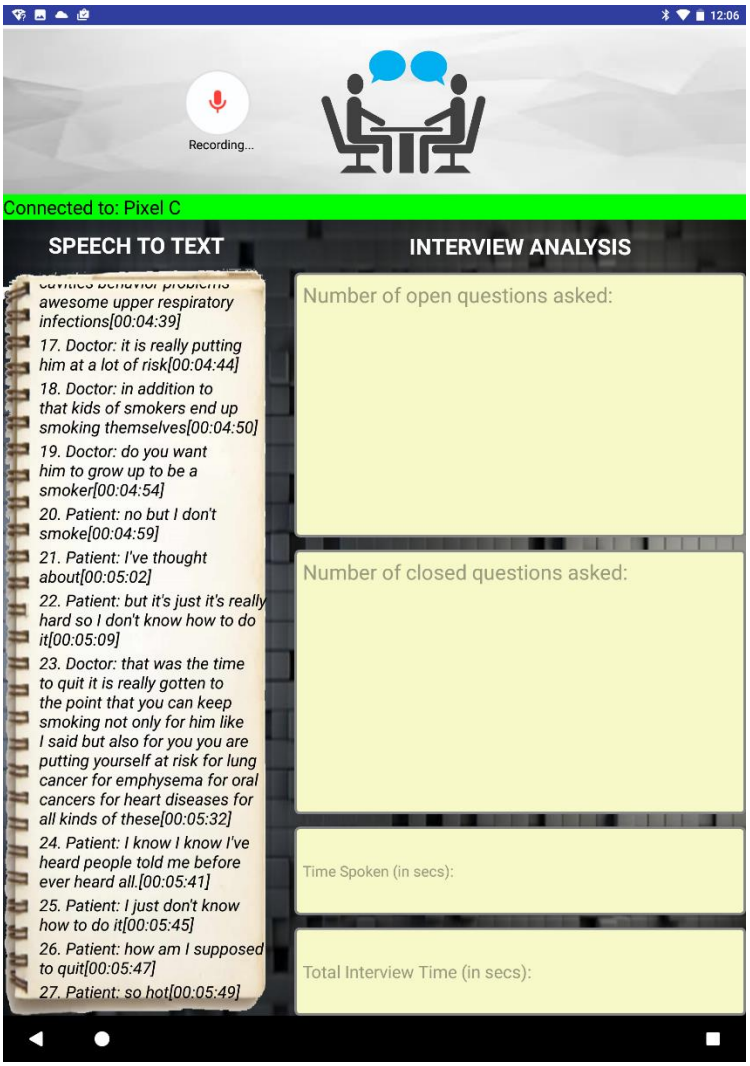


Figure 54: SCREENSHOT 20

SCREENSHOT 21: We do not analyze the patient's speech in our implementation and hence, as seen from the screenshot only the time spoken by the patient is calculated as 91 seconds and displayed along with the total interview time which is 274 seconds. The time spoken by the patient is used in the calculation of the percentage of time spoken by the doctor excluding the total time of silence in the interview.

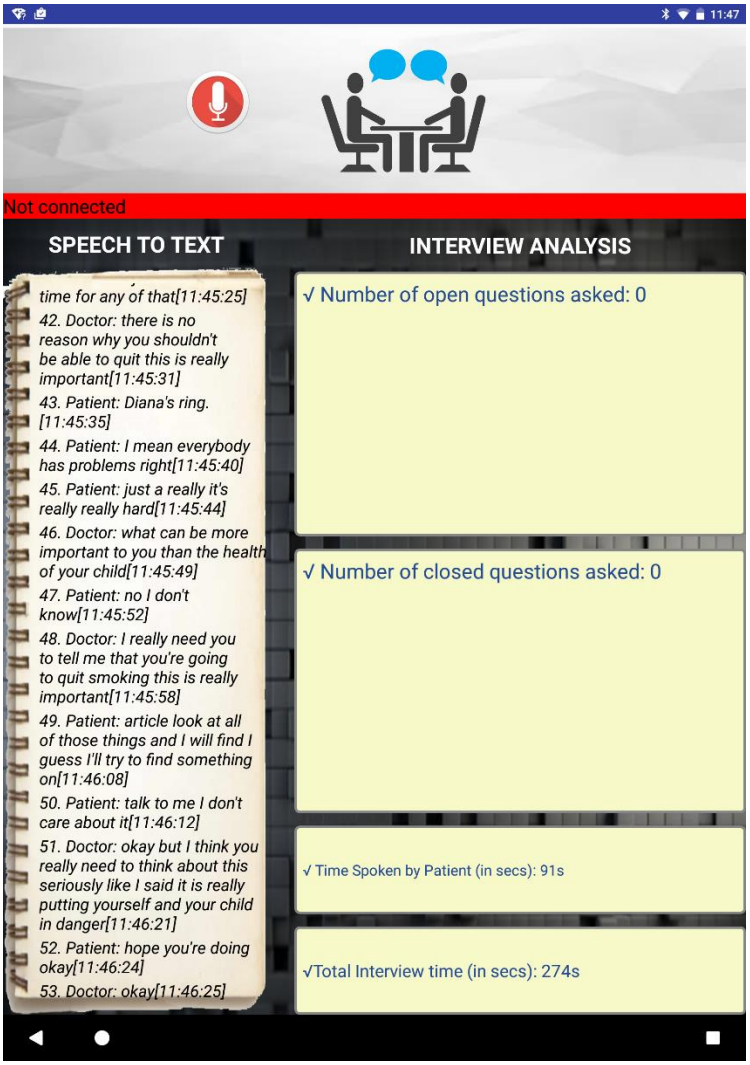


Figure 55: SCREENSHOT 21

The contents of the file that is saved after the completion of the interview is shown here:

**INTERVIEW ANALYSIS**

**----------**

**Open Questions are:** 4

1) What can you tell me about that

2) Point where you have to put tubes in his ears pretty sure here

3) There is no reason why you shouldn't be able to quit this is really important

4) What can be more important to you than the health of your child

**Closed Questions are:** 2

1) Are you smoking

2) In addition to that kids of smokers end up smoking themselves do you want them to grow up to be a smoker

Time Spoken by Doctor (in secs): 129s

Time Spoken by Patient (in secs): 91s

Total Interview time (in secs): 274s

Percentage of Time spoken by Doctor: 59%

**INTERVIEW CONVERSATION**

---

**Doctor:** okay so I don't prescription for antibiotic for Eden that should help with the ear infection but in looking to the check I mean it seems like he has had 6 or 7 just in the past year or so that is really a big problem

**Patient:** yeah it's pretty stressful for both of us I think it's really upset

**Doctor:** one of the primary risk factors for multiple ear infections in kids is smoke explosion are you smoking

**Patient:** yeah

**Patient:** yeah I do smoke but I don't smoke around him

**Patient:** DND hard not to smoke around him

**Doctor:** the fact that he is having these ear infections is indicating to me that he is being exposed to smoke and so what can you tell me about that

**Patient:** oh I don't know I mean I tried really hard on him

**Patient:** don't smoke in the car when he's home I go outside to smoke I just I mean I know it's bad and I know it's bad for him so I don't want him to be around it so I try really hard

**Doctor:** I really need you to quit smoking vote for your help and even did you know smoking around your child is associated with ear infections it could get to the point where you have to put tubes in his ears pretty sure here Also things like vitamin C deficiency cavities like dental cavities behavior problems other approaches play tree infections

**Doctor:** Its really putting him at a lot of risk in addition to that kids of smokers end up smoking themselves Do you want him to grow up to be a smoker

**Patient:** no but I don't smoke I'm I thought about quitting it's just

**Patient:** really hard so I just don't know how to do it

**Doctor:** now is the time to quit it's really gotten to the point where you can't keep smoking before him like I said you are putting yourself at risk for Lung Cancer for emphysema for oral cancers diseases for all kinds of bees

**Patient:** I know I know I've heard people talking before a heart attack

**Patient:** don't know how good or how am I supposed to quit it is so hard

**Doctor:** there is all kinds of things you can use now it is not as hard as it used to be you can use nicotine replacement there's patches there's gum there's inhaler there's nasal spray we can talk about medications you can try and text you can try zyban quit smoking you can go to there is hotlines you can call and talk

**Patient:** I just don't have time for any of that

**Doctor:** that is no reason why you shouldn't be able to quit This is really important

**Patient:** I understand. I know it is I mean everybody has problems right

**Patient:** just really it's really really hard

**Doctor:** what can be more important to you than the health of your child

**Patient:** no

**Doctor:** I really need you to tell me that you are going to quit smoking this is really important

**Patient:** I'm going to catch all these things and I will find I guess I'll try to find something and I'll talk to my doctor about it

**Patient:** okay

**Doctor:** okay well I think you really need to think about it like I said its really putting yourself and your child in danger

**Patient:** okay whatever okay

**Doctor:** okay

We have also calculated the relative error from the results obtained by using this app and the results that were calculated manually. These errors are shown in the tables below.

Manually, for the example of a **good interview** used in the experimental results above:

The number of open-ended questions were 6 and

The number of close-ended questions were 0

Table 9: Calculation of relative error in open-ended questions

| **Run** | **True Value** | **Observed Value** | **Relative Error** |
|---|---|---|---|
| 1 | 6 | 7 | -0.1667 |
| 2 | 6 | 5 | 0.1667 |

Table 10: Calculation of relative error in close-ended questions

| **Run** | **True Value** | **Observed Value** | **Relative Error** |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |

In **run 1**, the open questions that were identified were:

1) Sharp and it sounds like you are trying not to smoke around him why did you make that decision
2) What made you decide to quit smoking when you are pregnant
3) How are you successful when you could before
4) Where do you think you for right now
5) What made you say five rather than two or three
6) **It sounds like you have a lot of reasons "why" you would like to quit you have been successful today in the past**
7) Where do you think we should go from here

No close questions were identified.

The question 6 has been wrongly identified as an open question because of the word "why". The reason for this is our implementation checks for the open keyword in the paragraph and if successful, it considers it as an open question. But in the example shown above, even if the paragraph had an open keyword it is just a statement/summary of the patient's reply and not a question.

In **run 2**, the open questions that were identified were:

1) It sounds like you are trying not to smoke around him why did you make that decision
2) What made you decide to quit smoking when you was pregnant
3) How are you successful when you quit the four
4) What made you say five president two or three
5) Where do you think we should go from here

No close questions were identified.

In this run, only 5 questions were identified as open questions instead of 6. The 6$^{th}$ question which is "where do you think you fall right now" was not listed because the keyword "where" was missed during the conversion of speech to text. This might be because of the time gap between the completion of the old intent and the start of a new intent.

Manually, for the example of a **bad interview** used in the experimental results above:

The number of open-ended questions were 2 and

The number of close-ended questions were 2

Table 11: Calculation of relative error in open-ended questions

| **Run** | **True Value** | **Observed Value** | **Relative Error** |
|---|---|---|---|
| 1 | 2 | 4 | -1 |
| 2 | 2 | 3 | -0.5 |

Table 12: Calculation of relative error in close-ended questions

| **Run** | **True Value** | **Observed Value** | **Relative Error** |
|---|---|---|---|
| 1 | 2 | 2 | 0 |
| 2 | 2 | 1 | 0.5 |

In **run 1**, the open questions that were identified were:

1) What can you tell me about that
2) **Point "where" you have to put tubes in his ears pretty shortly here**
3) **There is no reason "why" you shouldn't be able to quit this is really important**
4) What can be more important to you than the health of your child

The close questions that were identified were:

1) Are you smoking
2) In addition to that kids of smokers end up smoking themselves do you want them to grow up to be a smoker

The questions 2 and 3 have been wrongly identified as open questions because of the words "where" and "why" used in 2nd and 3rd questions respectively. The reason for this is our implementation checks for the open keyword in the paragraph and if successful it considers it as an open question. But in the example shown above, even if the paragraph had open keywords, it is just a statement/summary of the patient's reply and not a question.

In **run 2**, the open questions that were identified were:

1) What can you tell me about that
2) **That is no reason “why” you shouldn't be able to quit really important**
3) What can be more important to you than the whole child

The close questions that were identified were:

1) one of the primary risk factors for multiple ear infections in kids is actually smoke explosion are you smoking

Here, only question 2 was wrongly identified as an open question for the same reason mentioned above. The reason for not wrongly listing the question “there is no reason “why” you shouldn't be able to quit this is really important” is because in this run it misrecognized the word “why” during conversion from speech to text and thus, when the grammar analysis was carried out on this text result, it did not find any open keyword to consider it to be an open question. The same reason of misrecognition applies for not recognizing the 2nd close question which is “in addition to that kids of smokers end up smoking themselves do you want them to grow up to be a smoker”.

Initially, before carrying out any experiments we manually wrote the scripts of few interviews by listening to the videos [8, 9]. In a way, this is speech recognition i.e., conversion of speech to text but human is involved in the process (Let's call this as "Original text"). Then we used these scripts for testing, where speech recognition was carried out without human involvement using Android Speech Recognition API (Let's call this as "Experimental result"). We have compared the text outputs of the doctor's speech of both these processes and the results are displayed in the following figures (i.e., figure 56 and figure 57).

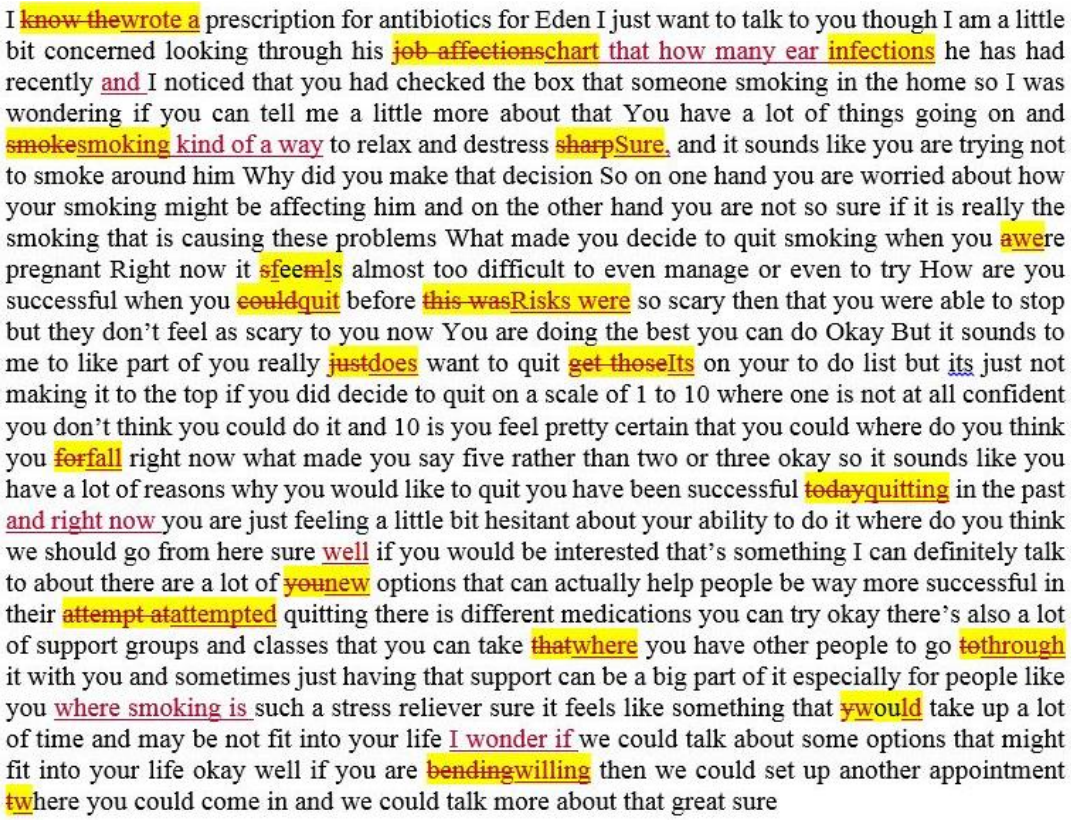
I ~~know the~~wrote a prescription for antibiotics for Eden I just want to talk to you though I am a little bit concerned looking through his ~~job affections~~chart that how many ear infections he has had recently and I noticed that you had checked the box that someone smoking in the home so I was wondering if you can tell me a little more about that You have a lot of things going on and ~~smoke~~smoking kind of a way to relax and destress ~~sharp~~Sure, and it sounds like you are trying not to smoke around him Why did you make that decision So on one hand you are worried about how your smoking might be affecting him and on the other hand you are not so sure if it is really the smoking that is causing these problems What made you decide to quit smoking when you ~~a~~were pregnant Right now it ~~s~~feem~~l~~s almost too difficult to even manage or even to try How are you successful when you ~~could~~quit before ~~this was~~Risks were so scary then that you were able to stop but they don't feel as scary to you now You are doing the best you can do Okay But it sounds to me to like part of you really ~~just~~does want to quit ~~get those~~Its on your to do list but its just not making it to the top if you did decide to quit on a scale of 1 to 10 where one is not at all confident you don't think you could do it and 10 is you feel pretty certain that you could where do you think you ~~for~~fall right now what made you say five rather than two or three okay so it sounds like you have a lot of reasons why you would like to quit you have been successful ~~today~~quitting in the past and right now you are just feeling a little bit hesitant about your ability to do it where do you think we should go from here sure well if you would be interested that's something I can definitely talk to about there are a lot of ~~you~~new options that can actually help people be way more successful in their ~~attempt at~~attempted quitting there is different medications you can try okay there's also a lot of support groups and classes that you can take ~~that~~where you have other people to go ~~to~~through it with you and sometimes just having that support can be a big part of it especially for people like you where smoking is such a stress reliever sure it feels like something that ~~y~~would take up a lot of time and may be not fit into your life I wonder if we could talk about some options that might fit into your life okay well if you are ~~bending~~willing then we could set up another appointment ~~t~~where you could come in and we could talk more about that great sure

Figure 56: Comparison of the Original text [8] and Experimental result for interview 1

Okay so I ~~don't~~wrote a prescription for antibiotic for Eden that should help with the ear infection but in looking ~~to~~through the ~~check~~chart I mean it seems like he has had 6 or 7 of these just in the past year or so That is really a big problem Well one of the primary risk factors for multiple ear infections in kids is smoke exp~~lo~~si~~on~~ure Are you smoking Well the fact that he is having these ear infections is indicating to me that he is being exposed to smoke and so what can you tell me about that I really need you to quit smoking ~~v~~bot~~e~~h for your healpth and ~~even~~for Eden Did you know smoking around your child is associated not only with ear infections it could get to the point where you have to put tubes in his ears pretty ~~sure~~shortly here Also things like vitamin C deficiency cavities like dental cavities behavior problems asthma other ~~approaches play tree~~upper respiratory infections Its really putting him at a lot of risk In addition to that kids of smokers end up smoking themselves Do you want him to grow up to be a smoker Well now is the time to quit It's really gotten to the point where you can't keep smoking ~~before~~not only for him like I said but also for you You are putting yourself at risk for lung cancer for emphysema for oral cancers for heart diseases for all kinds of ~~bees~~these Well there is all kinds of things you can use now It is not as hard as it used to be You can use nicotine replacement there's patches there's gum there's inhaler there's nasal spray We can talk about medications you can try ~~and text~~Chantix you can try zyban There is quit smoking groups you can go to there is hotlines you can call and talk There is no reason why you shouldn't be able to quit This is really important Well what can be more important to you than the health of your child I really need you to tell me that you are going to quit smoking this is really important Okay well I think you really need to think about ~~it~~this seriously like I said its really putting yourself and your child in danger Okay

Figure 57: Comparison of the Original text [9] and Experimental result for interview 2

After comparison, we have observed that there were two kinds of errors that occurred. Those are:

1. Misrecognition errors caused due to accent problems. Such errors are highlighted with yellow in the figures 56 and 57.
2. Not recognizing few words at all. This error is because of the time gap between the terminating an old intent and starting a new one due to the pause in speech by the user. These errors are underlined and displayed in red in the figures 56 and 57.

Table 13: Calculation of accuracy for interview 1 based on figure 56

| Title | Number of words | Percentage error (in %) |
|---|---|---|
| Total Number of words | 489 | Not Applicable |
| Misrecognition errors | 22 | 4.4989 |
| Loss of words | 19 | 3.8854 |
| Total errors | 41 | 8.3844 |
| Accuracy | 448 | 91.6155 |

Table 14: Calculation of accuracy for interview 2 based on figure 57

| Title | Number of words | Percentage error (in %) |
|---|---|---|
| Total Number of words | 382 | Not Applicable |
| Misrecognition errors | 18 | 4.7120 |
| Loss of words | 20 | 5.2356 |
| Total errors | 38 | 9.9476 |
| Accuracy | 344 | 90.0523 |

# CHAPTER 6

## Conclusion

The findings from the studies in this thesis support a number of conclusions with regard to the aims

- Motivational Interviewing can be a useful counseling style for promoting motivation for behavior change with broad applicability. Majority of studies have concluded that application of MI in treatment of patients elicits better and favorable outcomes than the conventional approaches. Hence, development of an Android based performance assessment system for MI training plays a major role in assisting the MI training by providing real-time instantaneous feedback to the trainees which helps them improve through the training sessions.
- We have successfully extended the Android's voice command interface to support long conversations between the participants in a training session. And the speech thus captured is converted into text which is later processed through grammar analysis in order to give feedback about their performance.
- Furthermore, the Android application we have developed comes in handy for the trainers of MI during evaluation. This user-friendly and hassle-free system can be easily used by medical professionals with any android device such as tablets or smartphones.

- Our experimental studies have demonstrated around 90% accuracy making this application an effective, reliable and consistent assessment tool for MI training and practice. We believe this new assessment technique will improve the current practice in training sessions.

**Future works**

Our future work involves improving the grammar analysis using various other NLP techniques in order to better classify the open-ended and close-ended questions. Also, the current grammar implementation doesn't support the scenario where two questions can be asked together, one after the other. Thus, we would like to explore many such scenarios and develop a grammar analyzer that handles all such situations efficiently.

Furthermore, we would like to build an assessment system that could also analyze reflective statements. These statements are those that express empathy, that summarize the patient's point etc. Including these in grammar analysis would help in providing better assessment of the trainee's performance in a training session.

We would also like to develop this application for other mobile platforms and explore other speech recognition engines.

We believe these future works will help mature this assessment for real-time training practices.

**REFERENCES**


1. McGinnis, J. M., & Foege, W. H. (1993). Actual causes of death in the United States. *Jama*, *270*(18), 2207-2212.
2. Conner, M., & Norman, P. (2005). *Predicting health behaviour*. McGraw-Hill Education (UK).
3. *Enhancing motivation for change in substance abuse treatment*. (2012). Rockville, MD: U.S. Department. of Health and Human Services, Substance Abuse and Mental Health Services Administration, Center for Substance Abuse Treatment.
4. *MOTIVATIONAL INTERVIEWING IN THEORY AND PRACTICE* (Unpublished doctoral dissertation). Linköping University, Sweden. (2010). Retrieved from http://www.diva-portal.org/smash/get/diva2:356212/fulltext01
5. http://www.workforcesnohomish.org/advance/iif/documents/training/motivationalinterviewhandout.pdf
6. Miller, W. R. (2000). Motivational enhancement therapy: Description of counseling approach. *COPYRIGHT STATUS*, 99.
7. https://www.umass.edu/studentlife/sites/default/files/documents/pdf/Motivational_Interviewing_Definition_Principles_Approach.pdf
8. https://www.youtube.com/watch?v=DDeXwF8Ff3E
9. https://www.youtube.com/watch?v=80XyNE89eCs

10. Training professionals in motivational interviewing. (November 2011). *The Health Foundation*. Retrieved from http://www.health.org.uk/publication/training-professionals-motivational-interviewing
11. http://www.motivationalinterviewing.org/about_mint
12. https://msdn.microsoft.com/en-us/library/hh378337(v=office.14).aspx
13. "Speaker Independent Connected Speech Recognition- Fifth Generation Computer Corporation".
14. https://www.inc.com/kevin-j-ryan/internet-trends-7-most-accurate-word-recognition-platforms.html
15. https://developer.android.com/reference/android/speech/SpeechRecognizer.html
16. https://cloud.google.com/speech/
17. https://www.ibm.com/watson/developercloud/doc/speech-to-text/index.html
18. https://developer.android.com/guide/topics/connectivity/bluetooth.html
19. Bayliss, D. (2016, June 16). Android RecyclerView Tutorial [Web log post]. Retrieved from https://www.raywenderlich.com/126528/android-recyclerview-tutorial
20. RecyclerView & ListView basic comparison [Web log post]. (n.d.). Retrieved from https://android.jlelse.eu/recyclerview-listview-basic-comparison-91e844a2fbc4
21. https://developer.android.com/reference/android/speech/RecognitionListener.html